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THE PETROCHEMICAL INDUSTRY IN DEVELOPING COUNTRIES: PROSPECTS AND STRATEGIES

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Preface

For the two previous Consultation Meetings on the petrochemical industry, two studies were prepared by the Sectoral Studies Branch as background papers, the First and the Second World-wide Studies on the Petrochemical Industry.[1/] For the Third Consultation to be held in Vienna from 2 to 6 December 1985, the present study has been prepared, in order to give to both the participants of the Consultation and interested Governments as well as petrochemical companies and other bodies or persons involved a global outlook of the latest developments, the present situation and the future prospects of this industrial sector. Special emphasis is laid on the emerging role of the developing countries, the opportunities offered to them and the problems that have to be overcome. Strategies and policies for the development of this industry are proposed for the different groups of developing countries and tentative conclusions are put forward. The importance of comprehensive and reliable information is underlined.

1/ First world-wide study on the petrochemical industry: 1975-2000 (UNIDO/ICIS.83), Second world-wide study on the petrochemical industry: process of restructuring (ID/WG.336/3).

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EXPLANATORY NOTES

References to dollars ($) are to United States dollars, unless otherwise stated.

A comma (,) is used to distinguish thousands and millions.

A full stop (.) is used to indicate decimals.

A slash between dates (e.g., 1980/81) indicates a crop year, financial year or academic year.

Use of a hyphen between dates (e.g., 1960-1965) indicates the full period involved, including the beginning and end years.

Metric tons have been used throughout.

The following forms have been used in tables:

Three dots (...) indicate that data are not available or are not separately reported.

A dash (-) indicates that the amount is nil or negligible.

A blank indicates that the item is not applicable.

Totals may not add up precisely because of rounding.

Besides the common abbreviations, symbols and terms and those accepted by the International System of Units (SI), the following abbreviations and contractions have been used in this report:

Economic and technical abbreviations

GDP	Gross domestic product
GNP	Gross national product
ISIC	International Standard for Industrial Classification
SITC	Standard International Trade Classification
ROI	Return on investment

Technical abbreviations

BTX	Benzene, toluene and xylene
DMT	Dimethylterephthalate
EB	Ethylbenzene
EDC	Ethylene dichloride
HDPE	High density polyethylene
LDPE	Low density polyethylene
LNG	Liquefied natural gas
LPG	Liquefied petroleum gases (propane, butane)
NGL	Natural gas liquids
PA	Polyamide
PAN	Polyacrylonitrile
PE	Polyethylene
PES	Polyesther
PP	Polypropylene
PS	Polystyrene
PVC	Polyvinyl chloride
SBR	Styrene butadiene rubber
TPA	Terephthalic acid
VCM	Vinyl chloride monomer

Definitions

For the scope of the present study it seems useful to define exactly the meaning of the different expressions being used, since in the literature and in the common usage many different interpretations exist.

Products and processes

Petroleum chemicals or petrochemicals are generally considered to be chemicals made from petroleum. For the purpose of this study, petrochemical is a noun referring to all chemical compounds which can be manufactured from natural hydrocarbons (crude oil, natural gas) by chemical processes and are intended for further processing either in the chemical or other industries. The same petrochemicals can also be produced from other sources: coal, wood, biomass, by chemical or biological methods (fermentation) and the products do not differ. Therefore, irrespectively of their origin and the manufacturing process all the above compounds will be considered as petrochemicals.

The petrochemical sector consists of six industries defined in SITC and ISIC terms:

Name of product group	SITC Rev. 1 code	ISIC code
1. Synthetic rubbers	231.2 599.76	3513.01
2. Synthetic fibres	266.21, 266.22 266.31, 266.32	3513.04 3513.31 3513.37
3. Organic petrochemicals	512 599.75	3511.03 3511.05 3511.07 3511.09 3511.10 3511.11 3511.13 3511.14 3511.15 3511.17 3511.18 3511.19 3511.21 3511.22 3511.23 3511.25 3511.30 3511.31 3511.33 3511.34 3511.35 3511.37 3511.38 3511.42 3511.43 3511.58 3529

4. Plastics	581.1, 581.2, 581.99	3513.10	3513.13
		3513.16	3513.19
		3513.22	3513.25
		3513.28	
5. Carbon black	513.27	3529.01	
6. Surfactants	554.2	3523.04	

To cover the whole field related to the petrochemicals the following terms should be defined:

- Raw materials (feedstocks)
- Primary petrochemicals
- Intermediate petrochemicals
- End petrochemicals
- Downstream industries.

Raw materials or feedstocks

Raw materials used for the manufacturing of the basic petrochemical products include liquid (crude, distillates, NGL) and gaseous (natural gas, LPG), hydrocarbons as well as coal and biomass. Production refining and processing of these materials for feedstock purposes is not included in the petrochemistry.

Primary petrochemicals (or basic petrochemicals) are the compounds manufactured from raw materials (hydrocarbons or others) falling into the following groups:

- Olefins
- Aromatics
- Syngas.

Olefins are the unsaturated (one or more double or triple bond) hydrocarbons. For this study only the following ones will be considered:

- Ethylene
- Propylene
- Butadiene
  (in the statistics, sometimes all the C_4 olefins are grouped together).

Aromatics are the unsaturated cyclic hydrocarbons containing one or more benzene rings. For this study only the following ones will be considered:

- Benzene
- Toluene
- Xylenes.

Syngas is a gas mixture containing a mixture of hydrogen and carbon monoxide with or without nitrogen.

Intermediates. Among the innumerable intermediates derived from the basic petrochemicals and used for the manufacturing of the different end products or serving other industrial utilization purposes, this study selected only a few, considered characteristic for the whole petrochemical field, but omitting all those which are important in the other chemical fields, like pharmaceuticals, plant protection, etc. The compounds considered are:

- Ethylene oxide
- Ethylene glycol
- Acetic acid
- Alkylbenzenes
- Therephthalic acid and dimethylterephthalate (DMT)
- Phthalic anhydride
- Ammonia 2/
- Methanol
- (Monomers used nearly exclusively for polymer production: vinylchloride (VCM), vinylacetate (VA), Styrene, etc. were not considered separately)
- Carbon black.

End products

Plastics

- Polyvinylchlorid (PVC)
- Polyethylene (PE)
- Polypropylene (PP)
- Polystyrene (PS)
- Others (including both thermoplastics and thermosettings).

2/ Depending on feedstock and process, ammonia can be classified here, but essentially it is an inorganic compound used in the fertilizer industry. Statistics do not include ammonia but in some cases mention will be made of ammonia production.

Rubbers

SR (synthetic rubber, including:
- Styrene butadiene rubber (SBR)
- Acrylonitrile butadiene styrene rubber (ABS).

Fibers

- Polyesters
- Polyacrylonitril
- Polyamid
- others (polypropylene etc.)
  (staple and continuous filament).

Petrochemistry includes the polymerisation and the fibre formation in all cases. Further processing belongs to the textile industry but often it is hard to draw a precise borderline. Many statistics on man-made fibre production include spinning, dying, texturing, etc. too.

Downstream industries (excluded from petrochemicals)

- Plastic processing
- Fibre processing
- Detergent confectioning
- Paint and varnish manufacturing
- Rubber processing
- Ammonia processing.

Energetics

Energy consumption means the total primary energy input in form of feedstock, utilities, power, steam etc. for the given purpose. Power consumption is converted according to the average efficiency of electricity generation and distribution: 1 kWH = 10^6 Joule[3/]

Specific energy consumption means the energy consumed for the production of one ton of product.

3/ For fuels and feedstock lower heating values (LHV) are used.

Consolidated energy consumption means the total energy consumed for a given intermediate or end product during the whole manufacturing process from the original feedstock input to the given product. E.g. the consolidated energy consumption of the PVC production includes the corresponding amounts of energy used for chlorine production, ethylene manufacturing, dichlorethane, VCM production and the polymerisation.

Economics

Capacity. Plant capacity: name plate capacity (latest data, taking into account the revampings or extensions) per year equal daily capacity x working days per year (with petrochemical plants, this is normally 330 days/year). Country capacity: sum of the plant capacities taking into account eventual revampings.

Production. Total output including captive uses also (not always available). Commercial figures, whenever available, are distinctly marked in footnotes.

Consumption global. For the purpose of the study, no account has been taken for inventory changes: annual production has been considered equal to consomption

Regional and country consumption. When no direct figures were available, the following equation was used:

$$\text{consumption} = \text{production} - \text{export} + \text{import}$$

Growth rate, annual

$$G_y = 100 \frac{\text{Quantity in year } (n+1)}{\text{Quantity in year } n} - 100 \quad \%$$

Growth rate, compound for X years

$$G_c = 100 \sqrt[X]{\frac{\text{Quantity in year } (n + x)}{\text{Quantity in year } n}} - 100$$

Growth rate, average, for X years

$$G_a = \frac{100 \cdot \dfrac{\text{Quantity in year } (n + x)}{\text{Quantity in year } n}}{X} - 100$$

I. INTRODUCTION

The present study, prepared by UNIDO, relates to the First and Second World-wide Studies,[4/] and to the recommendations of the Second Consultation and of other international meetings listed in annex 2.

1.1 Scope and aim of the study

The aim of this study is to give a global review on the status of the petrochemical industry, taking into account the development of the situation since the Second Consultation on the Petrochemical Industry held in Istambul, 22 to 26 June 1981. The study intends to define the concepts used, give a picture of the actual status and forecast possible future development of the industry with regard to capacities, production, demand and trade, in order to propose strategies and policies for the developing countries in the development of their own petrochemical industry.

4/ First world-wide study on the petrochemical industry: 1975-2000 (UNIDO/ICIS.83), Second world-wide study on the petrochemical industry: process of restructuring (ID/WG.336/3).

2. THE PETROCHEMICAL INDUSTRY: PAST AND PRESENT

2.1 History

The expansion of the iron and steel industry in the 19th Century created a steadily growing coke manufacturing industry. The by-products of this, viz., tar, coke-oven gas, low-calory coal beneficiation products called for some utilization, both for economic and environmental reasons. This was the start of coal chemistry. For more than a century, coal was the main raw material not only for the whole organic chemistry but also for many other chemical industries, such as city gas production, aromatic intermediates for the pharmaceutical, dyestuff industries, etc.

When in the 1940s (United States) hydrocarbons began to take over from coal as energy carriers, the most valuable products of the crude oil refining and natural gas processing, i.e. gasoline, diesel oil, lub-oils, etc. were reserved for motor fuel, power generation and household energy supply purposes, while the by-products, or less demanded products (straight run naphtha, ethane, LPG, etc.) found an outlet in the organic chemistry, replacing the chemicals derived from coal. A co-operation, even a symbiosis between petroleum refining or natural gas processing and petrochemistry was created.

This co-operation was very flexible and always adapted itself to the local possibilities. A typical example of how the production of the same basic petrochemicals followed quite different routes, according to the market demand for petroleum refinery and gas processing products, is the production of olefins.

In the United States from the beginning crude refining was intended for maximum motor-fuel yield. A high degree of motorization created a broad market for gasoline while less use was found for the heavy refinery fractions, since power generation, industrial and household heating were using mainly natural gas or coal. On the other hand, with the relatively high ethane content of the American natural gas, it was possible to extract ethane at very little extra cost during the compulsory processing of the natural gas before feeding it into the pipeline grid. Ethylene production and ethylene chemistry were, therefore, in the United States primarily based on ethane cracking.

In Europe the situation was just the opposite. With few known natural gas reserves up to the 1960s the bulk of the European power generation, industrial and home heat energy supply shifted from coal to the then very inexpensive fuel oil, creating a big demand for the heavy refinery fractions. Motor fuel consumption was lower, due to the lower motorisation level. The typical European refinery was thus fuel-oil oriented. The light fractions, mainly naphtha, were necessarily co-produced in quantities exceeding the demand. Consequently, straight-run naphtha became practically the only feedstock for olefin production in Europe. The comparison between a typical American and European refinery product mix and the development trends can be seen in figure 1.5/

During the period 1980 to 1983 the whole petrochemical industry consumed only 8 per cent of the total naphtha and 10 per cent of the natural gas used world-wide. Everywhere, the regional and local pictures show a symbiosis of petroleum, gas, energy and petrochemical industries. The petrochemical industry uses the less demanded hydrocarbon fractions, manufactures higher value products out of them, and thus enhances the economics of the whole industrial operation. But the overall economic viability is nevertheless always decided by the energy-side, representing the bulk of production. This is true even when the refineries, petrochemical enterprises and fuel consumers are connected only by market forces.

The same situation is encountered with all alternative feedstocks. Processes based on coal, on biomass or on any other raw material are and will be developed with motor fuel substitution in mind. They will be commercially successful on a global basis as a substitute for the petrochemical feedstocks only, if the fuel produced is competitive and a similar symbiosis between the energy sector and chemistry can be implemented.

Geographically, the petrochemical industry adapted on the one hand to the situation created by the oil refining and gas processing and on the other hand to the market. Oil fields were generally far away from the main consumption

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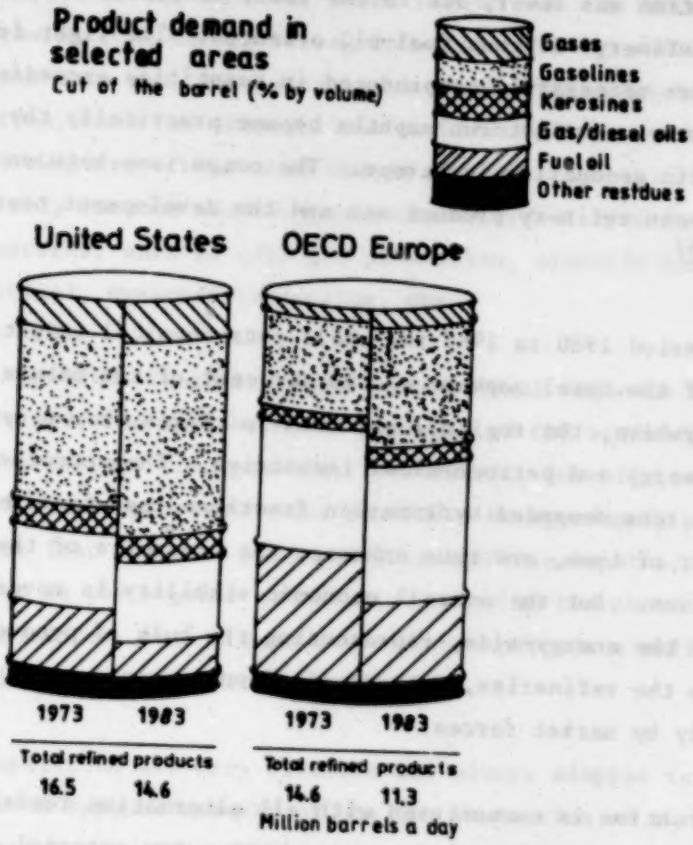
5/ Energy in profile, Shell Briefing Service, Number Five, 1984.

Figure 1. Product demand in selected areas



Source: Energy in profile, Shell Briefing Service, Number Five, 1984.

areas. It was simpler and cheaper to ship the crude to the big markets and build the refineries in the consumer areas. Basic petrochemical plants are usually situated near the refineries or in the area covered by their product pipeline grid. An exception is the United States where the Gulf area became the main petroleum and petrochemical centre and products are shipped by pipelines and barges to the other parts of the country. End-product manufacturing plants, depending on local circumstances, are placed somewhere between the basic petrochemical plant and the market. The result of this development was that the majority of the hydrocarbons produced in the developing countries was shipped to the developed countries, where most of it served as fuel, while the less demanded fractions were utilized for petrochemical purposes. Part of the end-products was exported to developing countries.

2.2 Position and structure of the petrochemical industry

2.2.1 Position

The position of the petrochemical sector in the whole chemical industry can be defined in many different ways. There is really no universal understanding either of the exact meaning of petrochemistry, or of the classification method to be adopted. To define the scope and field of this study, the following scheme was used (see figure 2). The chemical industry[6/] is first divided into two branches: heavy and fine, both subdivided into organics and inorganics (there are other schemes where the order is reversed, the two main groups being inorganics and organics, both divided into heavy and fine chemicals). The petrochemical industry can be identified with the heavy organic group. Almost all of this group is certainly petrochemistry today. However, the boundaries with the heavy inorganics and fine organics are somewhat blurred. By its chemical composition and its connection to the fertilizer production, ammonia is an inorganic product but because of its process technology and feedstock it is often included in the petrochemical field. Some organic compounds like plasticisers, surface active agents and

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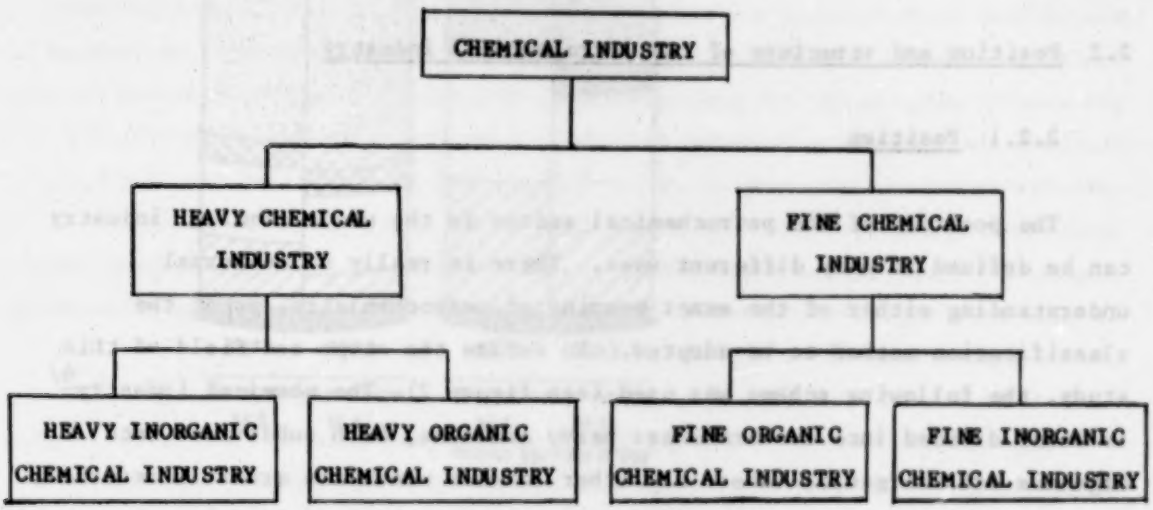
6/ For the terms used, please refer to definitions, page ix.

more complex intermediates for the manufacture of the pharmaceutical and plant protection products, although they are fine chemicals, are often grouped with the petrochemicals. For this study, the definitions of page ix will be used.

The heavy chemical industry produces the main basic compounds for the manufacturing of chemical end products and for other industrial purposes. It has two completely different branches, the inorganic and the organic heavy industry.

Figure 2. Structure of the chemical industry



From the beginning the heavy inorganic industry has been a branch composed of individual, independent production fields with no or minimal links and inter-dependences between them. Each field has its own raw material basis. Thus no closely interwoven complex structures are necessary.

On the other hand, the heavy organic industry was from the beginning a closely interrelated complex based on the same group of raw materials. This raw material group was always some by-product or at least less valuable product derived from a processing for the main user, the energy sector. The common raw material basis, the multiplicity of the simultaneous reactions leading to several products in the same process, and the possibility to use several feedstocks for the same prodution purpose led to this complex structure.

2.2.2 Structure

In the petrochemical industry, apart from the usual production chain leading from the feedstock to the end products, there are many ramifications. There are alternative uses for the same product as well as alternative raw materials and processes for the same manufacturing purpose. The result is a rather complicated, highly interwoven structure, difficult to overview. A diagram trying to embrace all the interconnections would be rather like a labyrinth even for a chemical engineer if not specialized in this field. In order to give a relatively simple but not untrue picture of this industry, two diagrams are presented. Figure 3 shows the relationships between the main petrochemical compounds discussed in this study, omitting all the other ramifications. It gives a fairly good overall view of the main connections, but does not reflect the relative weight of the different connections, feedstock uses and product distribution. A similar simplification is applied to figures 4(a) and (b) presenting the same relationship, but the feedstock and products streams are represented proportionally. The scale of the crude and gas processing however had to be reduced to 1:10.

Figure 3 includes the possible main alternative feedstocks: coal and biomass. This is to present a clear picture of their eventual place in the future structure of the industry. Figures 4(a) and (b), however, deal only

Figure 3. Structure of the chemical industry

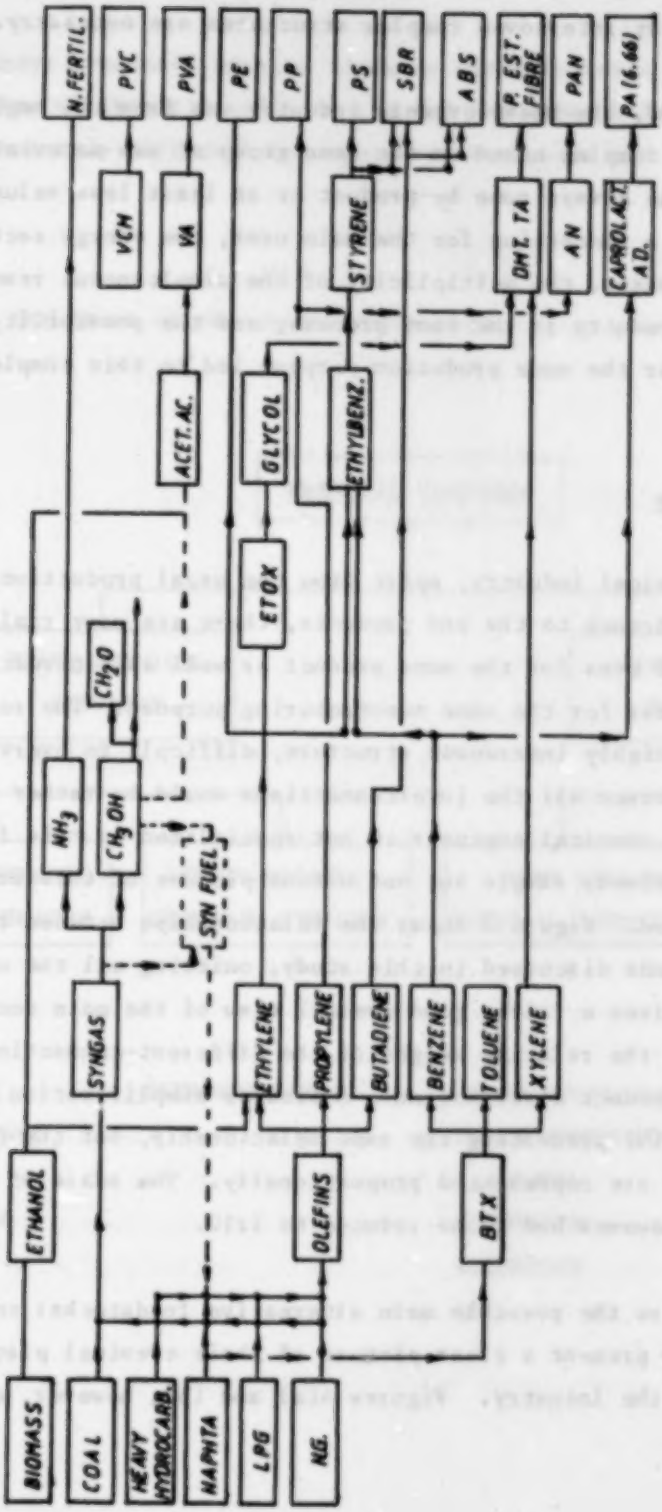


Figure 4(a). Material flow diagram - hydrocarbons (million tons/year)

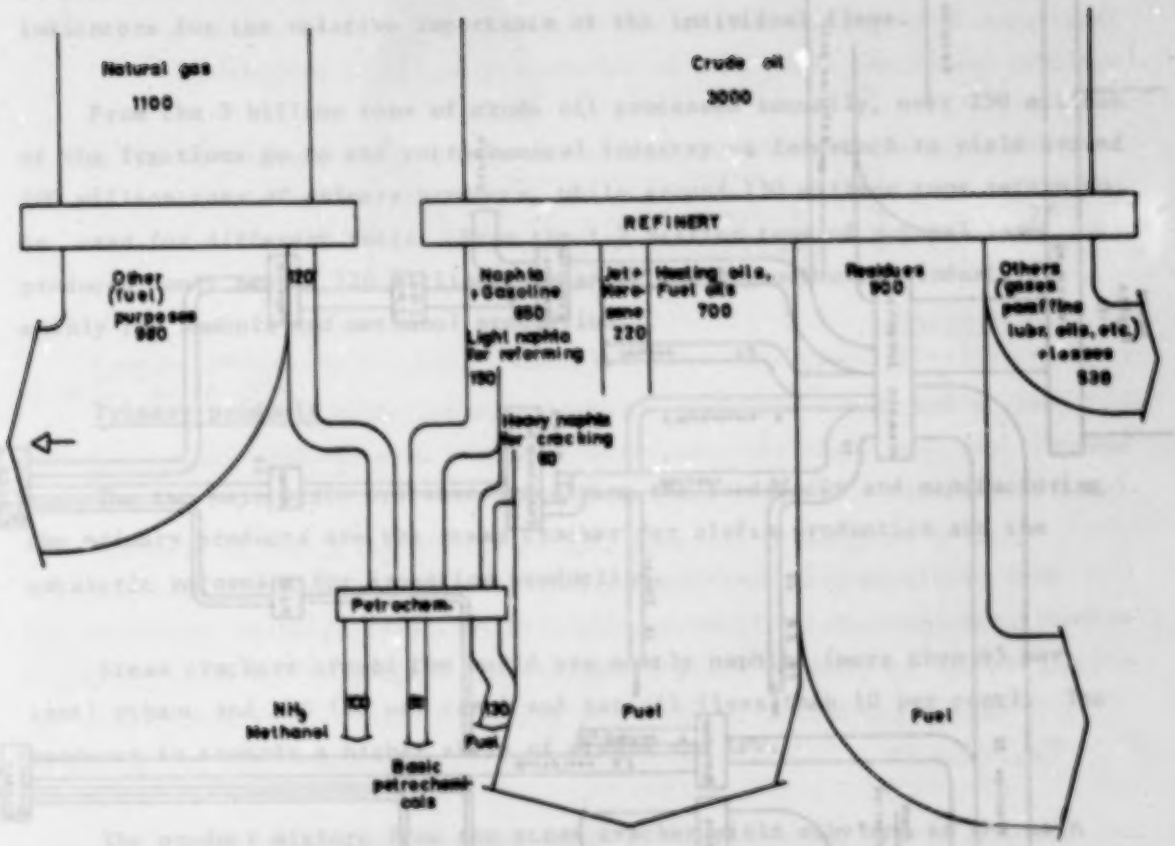
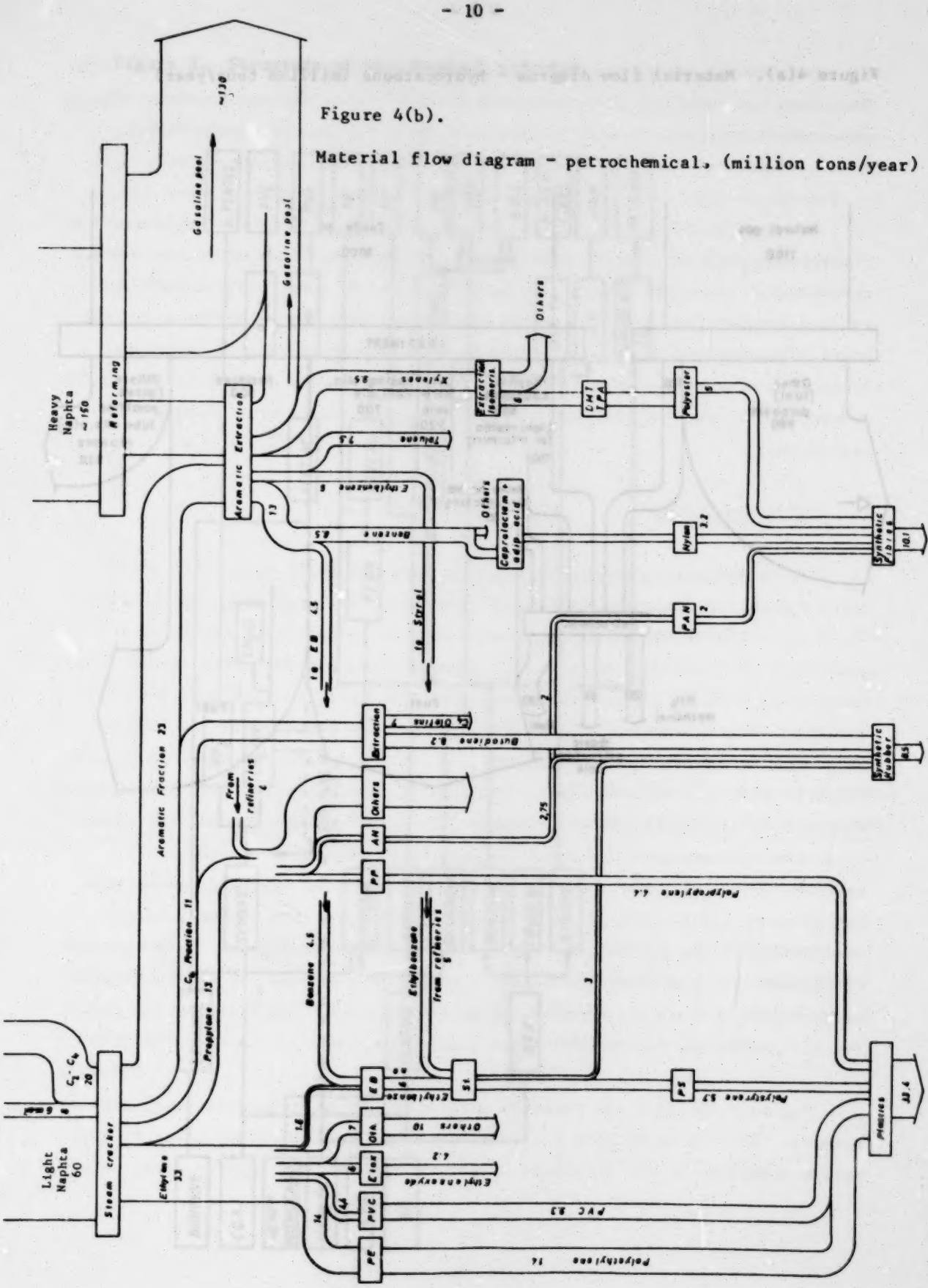


Figure 4(b).

Material flow diagram - petrochemical. (million tons/year)



with the hydrocarbon feedstocks, since coal and biomass have today only local importance in the petrochemical field. For ammonia and methanol production only coal and liquid hydrocarbon as feedstock were presented. The figures in the diagrams based on the data of 1980 are only approximate and serve as indicators for the relative importance of the individual flows.

From the 3 billion tons of crude oil processed annually, over 250 million of the fractions go to the petrochemical industry as feedstock to yield around 100 million tons of primary products, while around 130 million tons return to be used for different fuels. From the 1.2 billion tons of natural gas 7/ produced, only around 120 million tons serve the petrochemical industry, mainly for ammonia and methanol production.

Primary products

The two main basic processes receiving the feedstocks and manufacturing the primary products are the steam cracker for olefin production and the catalytic reforming for aromatics production.

Steam crackers around the world use mostly naphtha (more than 65 per cent) ethane and LPG (25 per cent) and gas oil (less than 10 per cent). The tendency is towards a higher share of ethane and LPG.

The product mixture from the steam cracker yield ethylene as the main product in the separation process but also, depending on the feedstock, a whole series of different by-products. Other olefins, such as propylene, butylene and butadiene are important primary products for the petrochemical industry. The liquid fractions return mostly to the refinery for further processing, yielding mainly aromatics, while the so-called green oil is the best feedstock for carbon black manufacturing.

7/ For consistency in the units used, natural gas was converted from Nm^3 to metric tons 1000 Nm^3 natural gas = 0.850 MT.

From the heavy naphtha fraction the catalytic reformer produces a valuable blending component for the gasoline pool, viz. a fraction with high aromatic content. One part of the aromatics thus produced is diverted to the petrochemistry. Practically all the benzene, toluene and xylenes produced today come from two sources, catalytic reforming and steam cracking. The refinery operations yield also an important quantity of propylene.

The total world production of the two main primary product groups was 57 million MT of olefins with a value of $US 25 billion and 40 million MT of aromatics with an estimated value of $US 11 billion.[8/]

Intermediates

Only a few of the countless intermediates are shown in the figures, however, the most important ones, leading to the main end products considered (plastics, rubbers, fibers), are included.

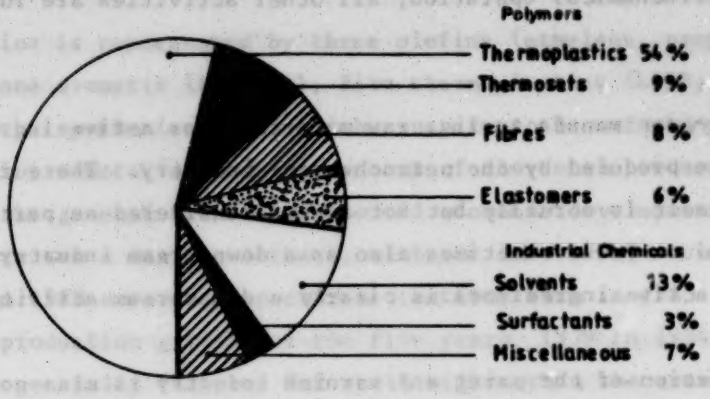
Many others such as detergents, pharmaceuticals, dyestuffs, paints, solvents etc. go directly to user industries but their relative importance for the whole of the petrochemical industry is less marked.

End products

Figure 5 shows the end product demand pattern for Western Europe. Thermoplastics, fibres and elastomers, the three sectors considered in this study, represent nearly 70 per cent of the total demand but their role is even more pronounced; they are setting the pace for production trends as well as for technical development.

8/ SRI International Business, Rep. No. 617.

Figure 5. Petrochemical demand in Western Europe, 1977 (by volume)



Source: Prospects for petrochemicals in Western Europe, Shell Briefing Service, March 1980.

Downstream products

The bulk of the petrochemical output, however, is composed of such substances which, with the addition of different auxiliary materials (plasticizers, dyes, etc.) need only some mechanical treatment (forming, moulding, spinning) to become either consumer goods or parts or raw materials for other industries. This processing forms the so-called downstream industries of petrochemicals (forward integration).

The borderline between petrochemical and downstream industry is in reality, somewhat diffuse. In plastics, the polymer production in powder form is undoubtedly a purely petrochemical process. Master-blend and granulate manufacturing, which is typically a mechanical processing, is, however, often performed within the plant where the polymerization takes place and is considered as a petrochemical operation. The processing of the polymer powders, master blends, granulates by injection-moulding, extrusion, calendering, etc. to ready-made products is once more unequivocally a downstream operation.

In the field of man-made fibres, production of the polymer or polycondensate chips, where appropriate, is also an uncontestedly petrochemical activity. Filament and yarn spinning, dying, before or after spinning, or texturising can be considered both ways. Further processing is once more the field of the textile industry.

In the rubber industry, the situation is clear. The production of the polymers is a petrochemical operation, all other activities are rubber processing.

In the detergent manufacturing, raw materials for active ingredients (surfactants) are produced by the petrochemical industry. The surfactant manufacturing itself is normally but not always considered as part of the petrochemical industry but sometimes also as a downstream industry. Detergent production from active ingredients is clearly a downstream activity.

The delimitation of the paint and varnish industry is also not clear cut. Paint and varnish manufacturing itself is not a petrochemical activity but production of the synthetic resins and organic solvents the main components of modern paints, can be considered both ways.

In this study, the borderline of the downstream industries is taken to the greatest extent possible to include all the activities which are strictly and unequivocally of a petrochemical nature.

This basic structure is only a single aspect in a continuously changing situation. There are both fluctuations and continuous trends. The same figure for the year 1990 will probably show shifts towards less naphtha, but more LPG and ethane use with the corresponding modifications in the primary product mix, but on the whole, the pattern will probably be preserved.

2.3 The recent development of the industry

The tables in annex 1 give a statistical summary of the production, capacity and trade development between 1975 and 1984.[9/]

9/ Production, consumption and capacity data are given in quantity terms, which are more convenient to use for the purposes of this study. The trade figures in table A.13 through A.17, expressed in monetary units, and their statistical evaluation were calculated using the data from "The petrochemical industry: the sector in figures", volume II or this study.

The general picture emerging from these tables is the following.

Production is represented by three olefins (ethylene, propylene and butadiene), one aromatic (benzene), five thermoplastics (LDPE, HDPE, PP, PVC and PS) and the synthetic fibres which constitute the main body of petrochemical products (around 70 per cent of the total production). All of them follow the general trend of the world economic development. Between 1979 and 1982 there was a serious setback, with the lowest values in 1981 and recovery from 1982 onwards, expected to continue also in 1985. The extent of the overall production growth for the five years, 1979 to 1984, is less than expected and generally forecast but still higher than the average industrial growth. The share of the developing countries is rising but at different rates and in most cases is around 10 per cent.

Capacity utilization was at its lowest level in 1981. Plant closures and a rising demand increased capacity utilization to over 80 per cent in most sectors up 1984 and even better figures are expected for 1985. The start up of new capacities seems to correspond to the expected rise in demand.

From the cumulative total world petrochemical production only less than 10 per cent enter international trade. The general tendency is an exchange of petrochemical products between the industrialized countries and a relatively high export from the industrialized to the developing countries. Export from the developing countries is in its infancy only. Their petrochemical imports represent a relatively small part of the global imports and even less of the world petrochemical production, form nevertheless a substantial part of their total consumption, usually more than half. All trends show a rapidly expanding role of the developing countries.

2.3.1 Production

Primary petrochemicals

Ethylene production (table A.1) dropped severely in the period 1980-1982 with 1981 the lowest, but even in 1982 had reached only 90 per cent of the 1979 level. The two consequent years showed a 13 per cent and 9 per cent rise

respectively and the 1979 level was finally surpassed in 1983. In 1984 it was 12 per cent over the 1979 production figures, giving a 3.5 per cent per year compound growth rate for the five year period 1979 to 1984. Ethylene production in the industrialized countries rose by only 9 per cent, corresponding to a compound growth rate of 1.7 per cent per year, while in the developing countries the corresponding figures were 62.5 per cent and 10.2 per cent per year respectively. The share of developing countries rose from 7.1 per cent in 1979 to 11.2 per cent in 1984.

Propylene production (table A.2) followed similar trends. In 1982 global production was 5 per cent lower than in 1979 but the drop was more severe in the industrialized countries. It amounted to 7.8 per cent while in the developing countries a 31 per cent growth occurred. In 1983 and 1984 global growths of 9 per cent and 7 per cent respectively led to an overall five years' growth of 11.25 per cent or a compound growth rate of 2.33 per cent per year. Over the period 1979 to 1984 this represents only a 8.5 per cent and a 1.6 per cent compound growth rate for the industrialized countries, while the corresponding figures for the developing countries are 63 per cent and 11.2 per cent per year respectively. The share of the developing countries grew from 6 per cent of global production in 1979 to 8.8 per cent in 1984.

The butadiene (table A.3) curve is similar, but the trends are less marked, due to the competition of natural rubber and the technical development in tyre production. Global production growth was only 10 per cent (1.8 per cent yearly), with a rise of 8.5 per cent (1.6 per cent yearly) in industrialized countries and 32 per cent (5.45 per cent yearly) in developing countries. The share of the developing countries in world-wide butadiene production rose from 8.6 per cent to 10 per cent.

Benzene (table A.4) fared less well. Even in 1983 it could not reach the 1979 production level and stood at 92.6 per cent. The developing countries, however, realized a constant growth: 8.5 per cent in 1982 and 11 per cent in 1983, giving a 38 per cent (8.4 per cent yearly) rise for the four year period of 1979 to 1983. The share of the developing countries rose from 6.9 per cent in 1979 to 10.25 per cent in 1983.

Thermoplastics

The main thermoplastics (PE, PP, PVC and PS) together moved around the 40 million metric ton/year level, with similar fluctuations. The global growth rate for the four years, 1979 to 1983, was 5 per cent (1.3 per cent per year) but in the developing countries a constant growth (52.6 per cent in four years, 11 per cent per year) was observed, raising their share from 9 per cent in 1979 to 13.2 per cent in 1983.

Among the thermoplastics polypropylene (table A.5) was the most successful. Production showed a 49 per cent growth (8.5 per cent/year) globally in five years, 112 per cent (17.2 per cent/year) for the developing countries and 46 per cent (7.8 per cent/year) for the industrialized countries. Even so the developing countries' share was only 10 per cent. Polypropylene is one of the newest products in this field and is in the ascending part of the development curve.

Less successful was PVC (table A.6) with an insignificant growth rate (0.9 per cent in four years). The production remained below the 1979 level in the industrialized countries even in 1983, but the 59 per cent increase in the developing countries' production raised their share from 13 per cent to 20.6 per cent. PVC is the oldest and most established thermoplastic.

The LLDP and LDP (table A.7) as well as HDPE (table A.8) production figures lie between those of polypropylene and PVC. Interesting enough, the low density types, in spite of the technical innovation (LLDP) remained on the same production level in the industrialized countries (1.4 per cent growth in 5 years) and advanced with 63.9 per cent (11.4 per cent/year) in the developing countries averaging a 12.2 per cent growth rate (2.3 per cent yearly). HDPE on the other hand showed a 23.5 per cent (yearly 4.3 per cent) global growth rate, doubling the production in the developing countries (15 per cent yearly). The industrialized countries also produced 18 per cent more in 1984 than in 1979 (3.4 per cent/year). The share of the developing countries remains in both cases low (8 per cent for HDPE and 13 per cent for the low density products).

The situation is worst for polystyrene (table A.9). Production in 1983 did not reach the 1979 level neither in the industrialized nor in the developing countries.

Synthetic fibres (table A.10) show contradictory figures in different sources. Due to the fact that statistics deal separately with continuous filament and yarn and that sometimes man-made fibres (including the cellulosic ones like rayon) are confounded with the synthetic fibres it is rather difficult to arrive at reliable figures for the individual chemical types. Table A.10 presents an overall picture for all synthetic fibres, including nylon, polyester and polyamids in all forms, yarn and continuous filament. The picture is rather gloomy with stagnation and even recession in 1983 with only a slight increase in the developing countries. The polyester fibre represents nearly half of the total volume on a global basis but over 55 per cent in the developing countries with polyamids (nylon) around 30 per cent and acrylics around 20 per cent globally and less in the developing countries.

2.3.2 Capacities

Table A.11 shows the existing and committed capacities for three olefins, considered as characteristic for the whole sector. Capacity utilization was low in the early 1980s. In 1984 more than 80 per cent of the capacity utilization e.g. for ethylene was reached and in the next years the expected new capacity of 12 per cent can be counterbalanced with an adequate rise in the demand. Less than 4 per cent yearly in three years would offset it.

2.3.3 Trade

International trade in chemicals is relatively low. With the restructuring going on, the trade will play a constantly growing role.

The general situation in petrochemical trade is that intertrade in the industrialized countries as a group roughly balances, but that the developing countries rely heavily on imports from the industrialized countries. Some trade in petrochemicals between developing countries is also starting.

The development of trade from 1975 to 1983, and 1984 and 1985 respectively (depending on the availability of data) is shown in tables A.12-A.13 (import), A.14-A.15 (export) and A.16-A.17 (trade balance) for the world, the developing, developed and centrally planned countries, as well as for the regions of the developing countries, all at 1975 constant $US.10/

Global trade

Trade showed a 30 per cent growth on a global level from 1975 to 1980 corresponding to a yearly rate of 5.4 per cent, while by 1983 a 9.1 per cent drop was observed (yearly rate: -2.9 per cent). Figures for 1984 are not yet available, but a recovery is assumed and the growth figure is expected to be around 3-5 per cent.

World chemical trade

Chemicals represented 7.8 per cent of the total world trade. Growth was more marked (42 per cent, yearly 7.2 per cent) in 1980 and the drop less marked (8.6 per cent, yearly 2.8 per cent) in 1983. Petrochemicals fared much better with a constant growth of 55 per cent (8.75 per cent yearly) for 1975-1980 and 12.5 per cent (yearly 4 per cent) in 1983. This raised the share of the petrochemicals in the world imports from 3.5 per cent in 1975 to 4.2 per cent in 1980 and 5.2 per cent in 1983. The share of the petrochemicals in chemical imports rose considerably. From 48 per cent in 1975 to 52.5 per cent in 1980 and 65 per cent in 1983. Export figures do not correspond exactly, but the difference in absolute figures is not significant.

Developing countries

The developing countries as a whole raised their imports by 37 per cent from 1975 to 1980 (6.2 per cent yearly) and the drop in 1983 was also less marked. It amounted to 7 per cent only (2.3 per cent yearly) thus their share

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10/ Data are based on "The petrochemical industry: the sector in figures", volume II of this study.

in world imports rose from 20.5 per cent in 1975 to 21.7 per cent in 1980 and 22.1 per cent in 1983. In exports the situation was reversed. The growth in the first period was less marked: only 14 per cent (2.65 per cent yearly) and the drop more serious, viz. 21.5 per cent (6.75 per cent yearly). In consequence the trade balance of the developing countries, which showed a surplus of $US 32,234 million (15 per cent of the trade) became negative in 1980 ($US -8,913; -3.6 per cent), which is not significant, and in 1983 the deficit rose to $US 44,413 (-19.2 per cent).

The situation in the chemical trade of the developing countries as a whole shows a different picture. The drop in the share of the chemical imports from 28.1 per cent in 1975 to 25 per cent in 1980 and 22.7 per cent in 1983 showed a decline in chemical purchases for trade balance purposes. At the same time the share of the chemical exports, in itself very low rose from 1.6 per cent in 1975 to 2.4 per cent in 1980 but dropped to 2.2 per cent in 1983 leading to a negative trade balance for the whole period.

In the petrochemical field, exports were insignificant in volume ($US 1-2 billions) and as a percentage of the developing countries' total exports (0.3-1.1 per cent) as well as a share of the world petrochemical chemical exports (2.2-4.1 per cent). However, petrochemicals are a constantly growing part of the developing countries' chemical exports. From 18.7 per cent in 1975 they rose to 50 per cent in 1983. With the emerging new big plants in the Near East and other regions beginning in 1985, a further important step will be made towards a significant role of the developing countries in petrochemical exports.

Petrochemical imports showed a constant upward trend. During the period 1975 to 1980 a growth rate of 52 per cent (yearly 8.75 per cent) was observed. The corresponding figures for the period 1980 to 1983 are 10 per cent and 2.9 per cent respectively. This raised the share of petrochemicals in the developing countries' chemical imports from 37 per cent in 1970 to 45.7 per cent in 1980 and 61 per cent in 1983.

Although the total petrochemical import is only around 5 per cent of the developing countries' total imports, this figure does not completely reflect the real situation. The consumption of petrochemical end products in the developing countries is one magnitude below that of the industrialized countries. Even a five-fold increase in the consumption would bring them only to a level corresponding to half that of the present level of the industrialized world, but would raise their total import by more than 20 per cent. This demonstrates how important the development of the domestic petrochemical industry is for the developing countries.

Developing regions

At a regional level Latin America accounts for more than half of the very low petrochemical export of the developing countries, and the growth rate is impressive. For 1975-1980 this amounted to 89 per cent (13.5 per cent yearly) and 69 per cent for 1980-1983 (18.7 per cent yearly). In East Asia, the trend is similar, but the absolute figures are lower. The export figures will be more interesting in the next few years when the new capacities being built will enter the market.

On the import side, all regions, except Latin America showed similar trends in total imports. North Africa, West Asia, South East Asia and East Asia registered a steady upward trend. South Asia and Tropical Africa had setbacks in 1983, but only Tropical Africa fell below the 1975 level. Chemical imports were rising generally in absolute terms but falling as a percentage of total imports. The upward trend in petrochemical imports was remarkable in all countries in absolute and also relative figures.

In 1980 Latin America had 25 per cent higher imports than in 1975, but imported 42 per cent less in 1983 than in 1980. The chemical and petrochemical imports followed this general trend. However, while the chemical imports were similar, the petrochemical trend went higher and dropped less (23 per cent and 34 per cent respectively in 1980/1975 and 47 per cent and 21 per cent respectively in 1983/1980). Latin America's share of

developing countries' total import fell from 30 per cent in 1975 to 27 per cent in 1980 and 17 per cent in 1983 with similar trends in the chemical and petrochemical imports.

Although new capacities have been commissioned in Latin America, the above effects can be attributed mainly to the economic situation. Taking into consideration the new capacities, the petrochemical import figures as compared to the general import trends, demonstrate the importance of the petrochemical products in the national economy of the developing countries.

2.3.4 Demand

While trade statistics are available for the whole of the petrochemical industry, production and demand figures can be found only by products. Production statistics can be assessed for most of the prodcuts but demand figures present more problems. It is rather difficult to find reliable data comparable to the production data. To estimate trends and arrive at conclusions, the group of thermoplastics was chosen and production and demand compared (see table A.18) for the years 1975, 1979 and 1983 on a regional basis. In general three industrialized regions, Japan, North America and Western Europe, export 5-25 per cent of their production, while the developing regions import between 30 per cent and 90 per cent of their demand. The total demand of the developing countries rose by 105 per cent between 1975 and 1979 and by 27 per cent between 1979 and 1983 while for the whole world the corresponding figures were 67 per cent and 5.4 per cent respectively. Import covered 56.4 per cent in 1975, 44.2 per cent in 1979 and 33.1 per cent in 1983 of their demand. The share of developing countries in the global consumption also rose from 13.3 per cent in 1975, to 16.4 per cent in 1979 and 19.7 per cent in 1983. The opinion was expressed that the real need would have been much higher and imports would have been greater, had the balance of payment situation allowed this. The per capita consumption of plastics in the developing countries which is about one-tenth of that of the industrialized countries as well as the foreign trade figures seem to give support to this opinion.

3. THE FUTURE OF THE PETROCHEMICAL INDUSTRY

The development of the world economic situation and that of the petrochemical industry showed that simple projection methods such as linear or exponential functions for steady growth cannot give a satisfactory impression of future development possibilities for the sector. Therefore instead of forecasting a constant rate of growth or tying the growth of the petrochemical industry to that of the GDP, this study tried first to identify the main factors influencing the behaviour of the petrochemical industry's development, assess their possible effect and analyze the alternatives for their future extention. In this way, the combined effect of all factors concerned will give an indication which scenarios might be worked out, taking into account the difference in the effect of these factors on the global and the regional development.

The effect of the following factors were taken into consideration:

(a) Global economic situation;
(b) Place and role of petrochemistry in this global situation;
(c) Feedstock supply;
(d) Technological development, R and D; and
(e) Restructuring.

3.1 Global economic situation

The main factor setting the pace for the development of the petrochemical industry is the global economic climate, which can be characterized by the GDP and the GDP growth figures respectively. This close relationship becomes evident if the growth curves for the petrochemical production is compared to that of total industrial production[11/] (figure 6), if the consumption of the main building block, ethylene is compared to the GNP[12/] (figure 7) or if the growth of ethylene demand and that of the GNP are drawn on the same graph[12/]

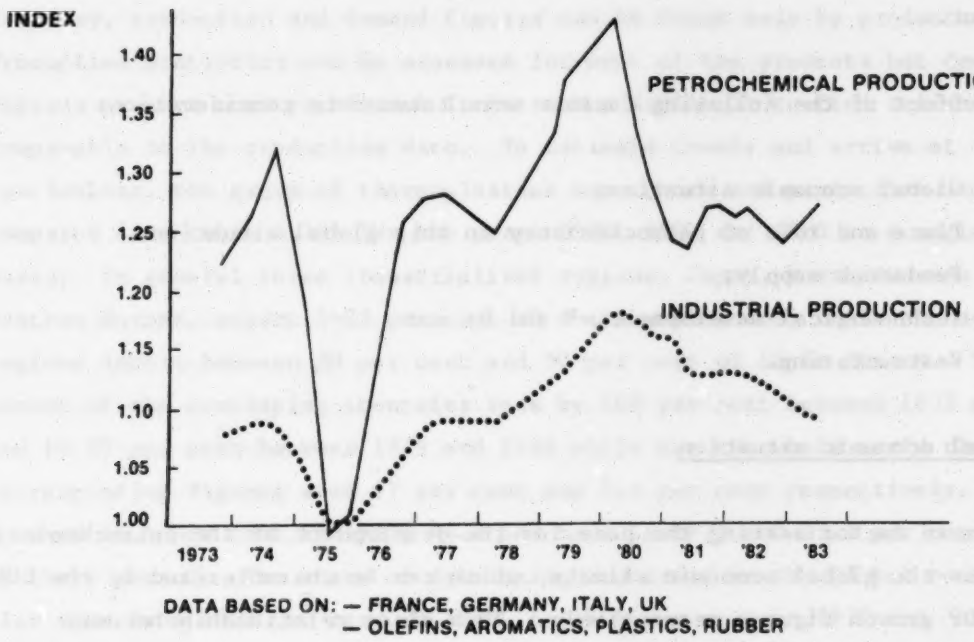
11/ D.R. Clair, The perils of hanging on (European Petrochemical Association, 17th Annual Meeting, Monte Carlo, 25-28 September 1983).

12/ How can the olefins industry survive in the 1990s, CEP, February 1984.

(figure 8). The shape of the curves is similar, the amplitude of the oscillations however are higher for petrochemistry. Another interesting graph[13] (figure 9) relates the chemical consumption of the different countries to their GDP per capita values (1982) on a log-log scale.[14]

These data are taken as prima facie evidence that a direct relationship exists between the GDP and petrochemicals both in long term trends and in transient fluctuations. This relationship is the basic one, while all other factors can have only modulating effects.

Figure 6. Production growth indices (1975 = 1.0)



13/ J.H. Hawey-Jones, New directions for the chemical industry (Chemistry and Industry, 19 December 1983).

14/ A similar relationship for the petrochemical industry was not available, but it was assumed, taking into account the share of the petrochemicals in the whole chemical industry of the countries involved, that the graph would remain very similar.

Figure 7. Demand for ethylene

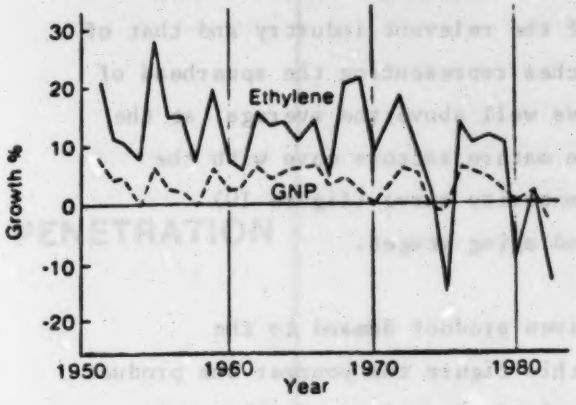


Figure 8. Ethylene versus GNP growth

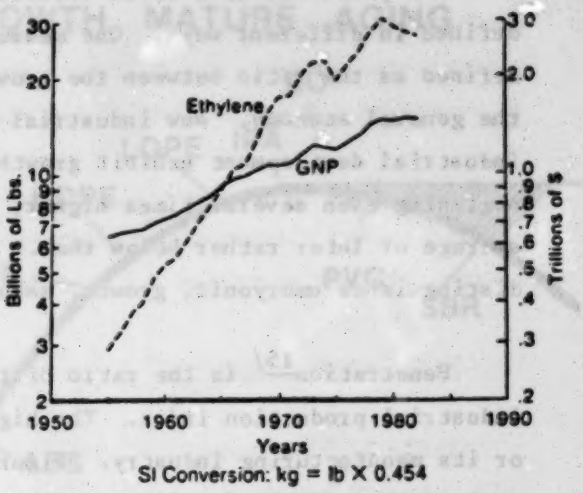
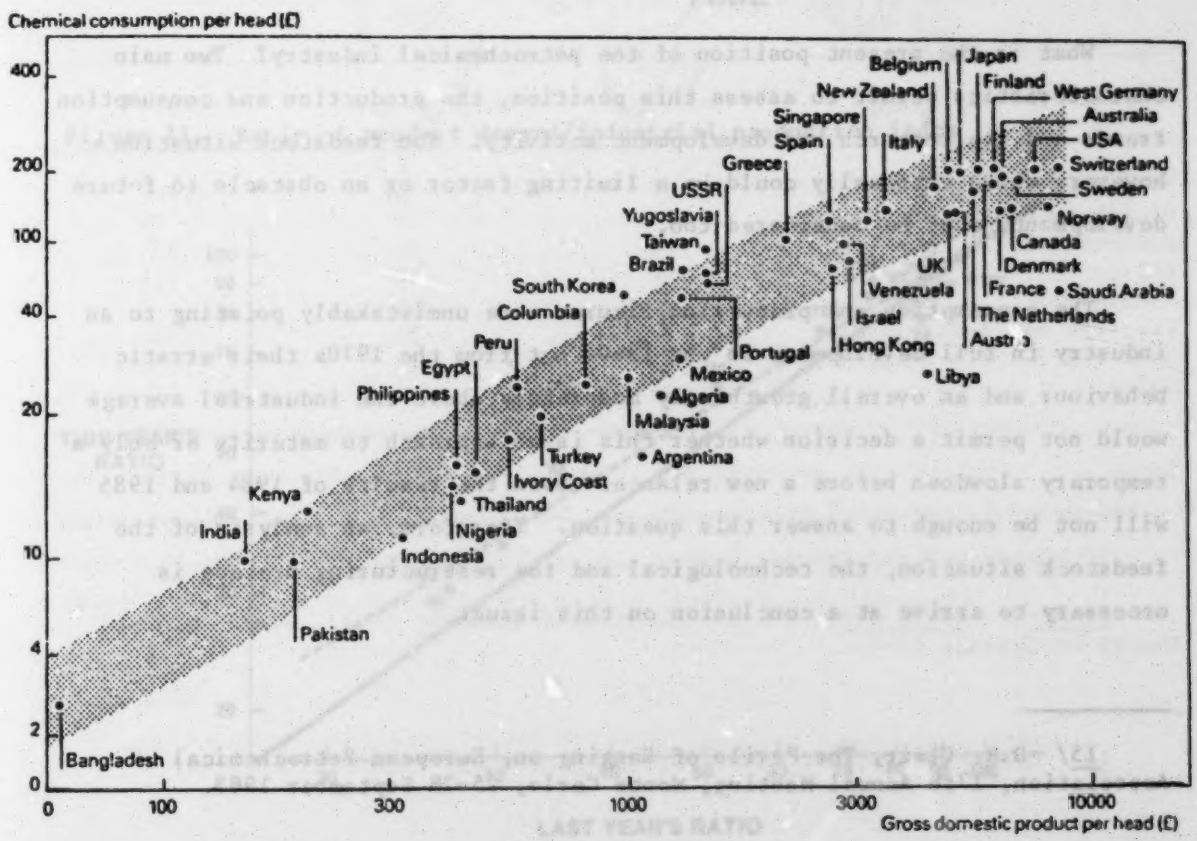


Figure 9. Chemicals consumption per head and GDP per head for 1982 (log-log scale



3.2 Petrochemicals - their place and role in the economy

The place and role of an industrial sector in the world economy can be defined in different ways. One measure is the maturity or penetration, defined as the ratio between the growth of the relevant industry and that of the general economy. New industrial branches representing the spearhead of industrial development exhibit growth rates well above the average, at the beginning even several times higher, while mature sectors move with the average or later rather below that. The maturity curve (figure 10) distinguishes embryonic, growth, mature and aging stages.

Penetration[15/] is the ratio of the given product demand to the industrial production index. The higher this figure the younger the product or its manufacturing industry. Figure 11 plots the values of this ratio against that of the immediate prior year on a log/log scale. The intersection of the line thus constructed with the 45° line gives the point where penetration will cease and the product reaches maturity.

What is the present position of the petrochemical industry? Two main characteristics permit to assess this position, the production and consumption trends and the research and development activity. The feedstock situation however, which eventually could be a limiting factor or an obstacle to future development, must be considered too.

The consumption and production figures were unmistakably pointing to an industry in full development in the 1960s but from the 1970s their erratic behaviour and an overall growth only moderately above the industrial average would not permit a decision whether this is an approach to maturity or only a temporary slowdown before a new relance. Even the results of 1984 and 1985 will not be enough to answer this question. Therefore, an analysis of the feedstock situation, the technological and the restructuring process is necessary to arrive at a conclusion on this issue.

15/ D.R. Clair, The Perils of Hanging on, European Petrochemical Association, 17th Annual Meeting, Monte Carlo, 25-28 September 1983.

Figure 10. Typical maturity curve, European petrochemical industry

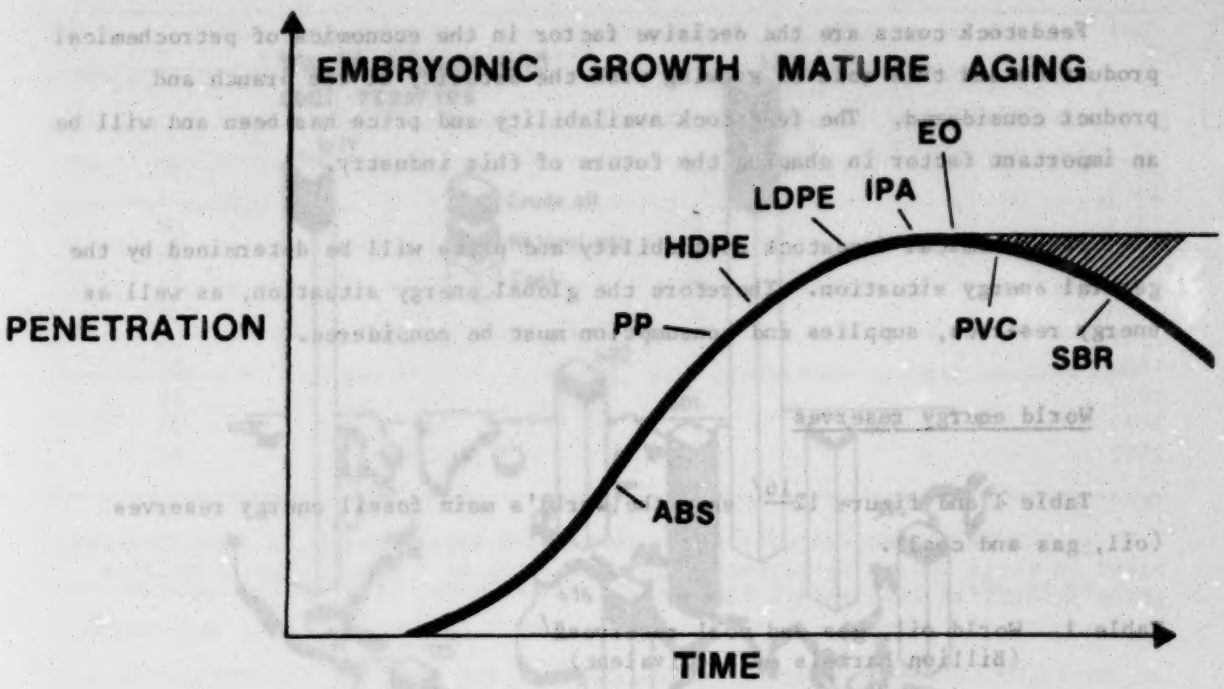
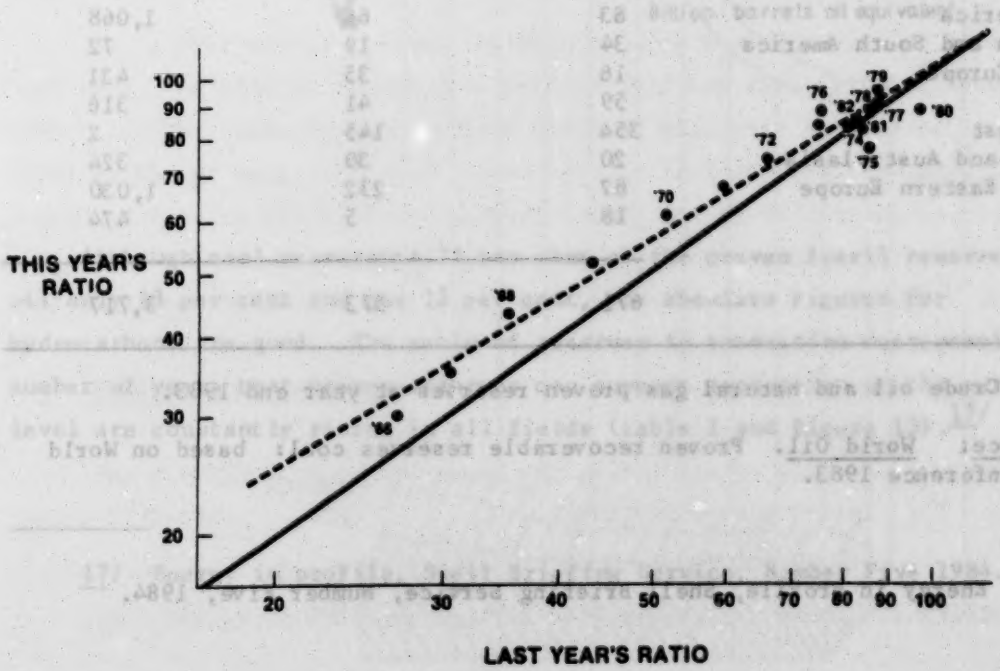


Figure 11. Ratio of product demand/industrial production index



3.3 Feedstock situation and trends

Feedstock costs are the decisive factor in the economics of petrochemical production and this role is growing with the maturity of the branch and product considered. The feedstock availability and price has been and will be an important factor in shaping the future of this industry.

Petrochemical feedstock availability and price will be determined by the general energy situation. Therefore the global energy situation, as well as energy reserves, supplies and consumption must be considered.

World energy reserves

Table 1 and figure 12[16/] show the world's main fossil energy reserves (oil, gas and coal).

Table 1. World oil, gas and coal reserves[a/]
(Billion barrels oil equivalent)

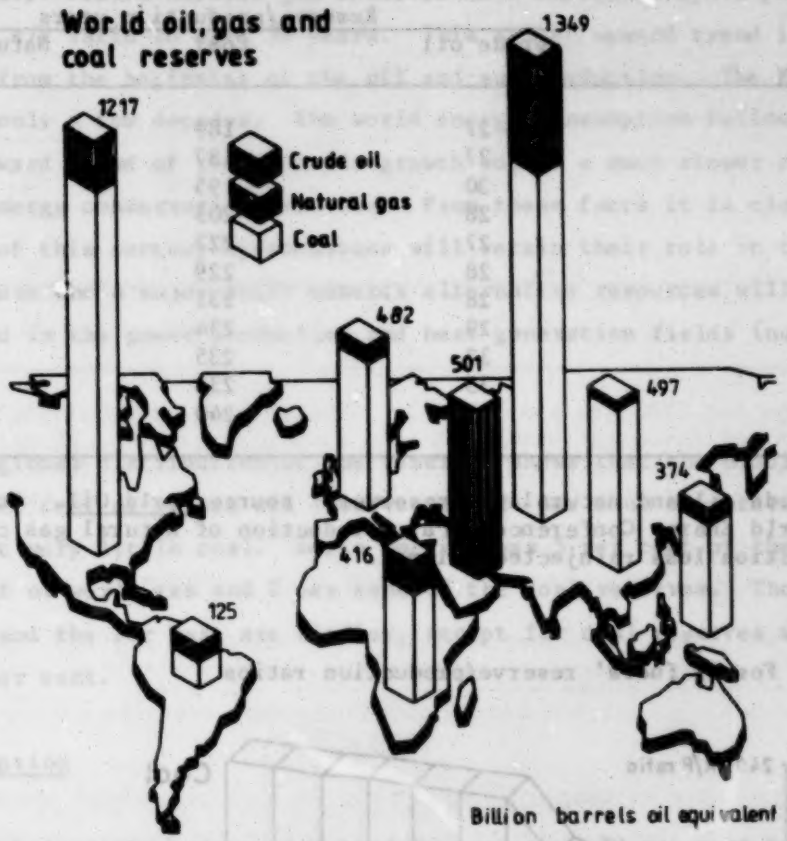
	Crude oil	Natural gas	Coal
North America	83	66	1,068
Caribbean and South America	34	19	72
Western Europe	16	35	431
Africa	59	41	316
Middle East	354	145	2
Far East and Australasia	20	30	324
USSR and Eastern Europe	87	232	1,030
China	18	5	474
Total	671	573	3,717

a/ Crude oil and natural gas proven reserves at year end 1983.

Source: World Oil. Proven recoverable reserves coal: based on World Energy Conference 1983.

16/ Energy in profile, Shell Briefing Service, Number Five, 1984.

Figure 12. World oil, gas and coal reserves



Although coal represents 75 per cent of the proven fossil reserves, with oil only 13 per cent and gas 12 per cent, the absolute figures for hydrocarbons are good. The ratio of reserves to production representing the number of years that proven reserves can support production at the current level are constantly rising in all fields (table 2 and figure 13).17/

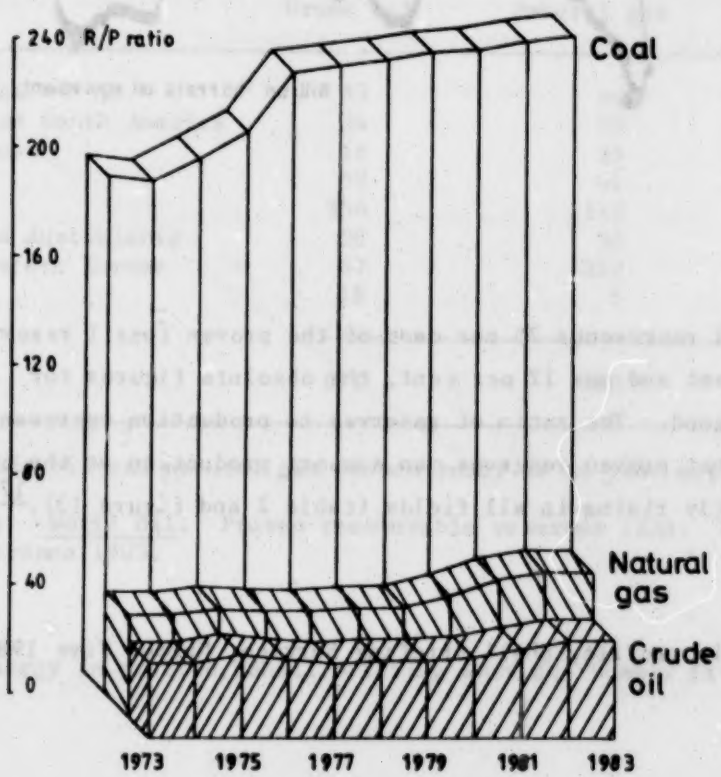
17/ Energy in profile, Shell Briefing Service, Number Five 1984.

Table 2. Fossil fuels: reserve/production ratios[a/]

	Reserve/production years		
	Crude oil	Coal	Natural gas
1973	27	189	37
1974	27	187	37
1975	30	195	39
1976	28	205	38
1977	27	227	38
1978	28	229	39
1979	28	231	39
1980	29	234	43
1981	32	235	49
1982	35	238	52
1983	35	240	52

a/ Crude oil and natural gas reserves: source World Oil. Coal reserves based on World Energy Conference data. Production of natural gas comprises gross production less reinjected volumes.

Figure 13. Fossil fuels' reserve/production ratios



A drop in annual production of 1 million barrels of oil contributed to this effect, but proven reserves also increased by 130 million barrels between 1973 and 1983. Proven natural gas reserves have increased by 61 per cent and thereby the R/P ratio to over 50 years. This slight upward trend is manifested from the beginning of the oil and gas production. The R/P ratio was always only a few decades. The world energy consumption follows the eventual upward trend of the economic growth but at a much slower rate, due to efficient energy conservation measures. From these facts it is clear that, up to the end of this century hydrocarbons will retain their role in the global energy picture and a major shift towards alternative resources will be mainly concentrated in the power production and heat generation fields (nuclear and coal).

The regional distribution of the reserves shows that the Middle East has nearly 53 per cent of proven oil reserves and 24 per cent of natural gas reserves but very little coal. Latin America has 5 per cent of the world oil, 3.3 per cent of world gas and 2 per cent of the coal reserves. The figures for Africa and the Far East are similar, except for coal reserves which are around 10 per cent.

Consumption

The global energy consumption rose by more than 70 per cent between 1963 and 1973, but only by 16 per cent between 1973 and 1983 (1.25 per cent yearly). The share of hydrocarbons (oil and gas) rose from 54 per cent in 1963 to 66 per cent in 1973 and then fell to 61.2 per cent in 1983. In absolute figures oil returned in 1983 nearly to the 1973 level as result of conservation and substitution by other fuels, while the quantity of natural gas increased by 25 per cent in these 10 years (table 3 and figure 14).[18/]

Crude oil production

The distribution of the crude oil production is given in table 4 for the years 1973-1983.

18/ Energy in Profile, Shell Briefing Service, Number Five 1984.

Table 3. World energy consumption (million barrels a day oil equivalent)

Million bdoe	1963	1973	1983a/
Oil	26.9	56.7	56.2
Coal	25.8	29.6	36.4
Natural gas	9.6	20.3	25.8
Hydro	4.2	6.6	9.4
Nuclear	-	1.0	4.8
Other	1.2	1.1	1.4
Total	67.7	115.3	134.0

a/ Data for 1983 are provisional. Others comprise industrial use of wood (e.g. Scandinavia and USSR), alcohol from biomass (e.g. Brazil), etc. Non-commecial use of traditional fuels (firewood, charcoal, agricultural waste, etc.) is excluded.

(-) Negligible.

Figure 14. World energy consumption (million barrels a day oil equivalent)

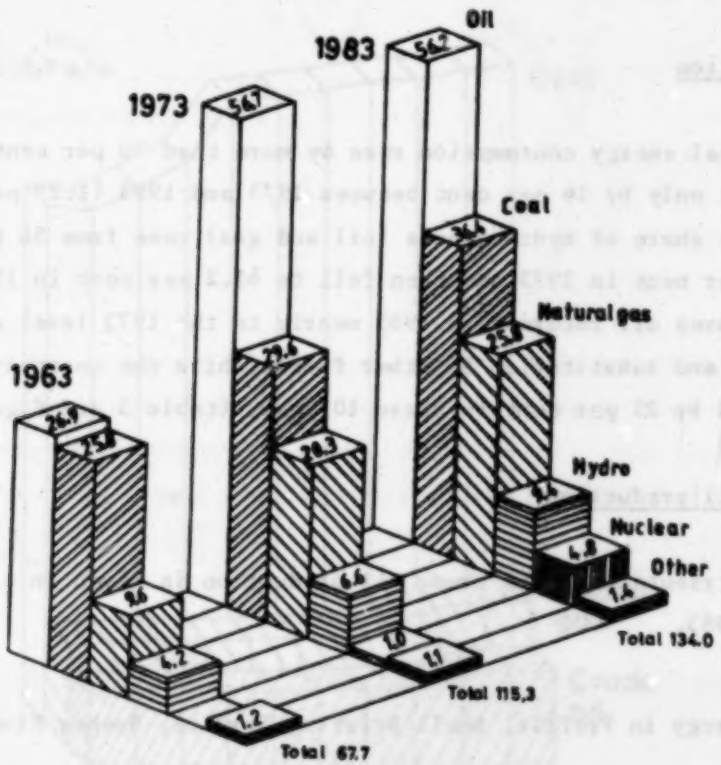


Table 4. World crude oil production[19/]

Million b/d	OPEC	OECD North America	OECD others	USSR Eastern Europe and China	Other countries	World
1973	30.9	10.9	0.8	9.9	3.1	55.6
1975	27.1	9.8	0.9	11.6	3.5	52.9
1977	31.2	9.5	1.7	13.0	4.1	59.5
1979	30.8	10.0	2.6	14.0	5.0	62.4
1981	22.5	9.7	2.9	14.2	6.1	55.4
1983	17.4	9.9	3.7	14.4	7.1	52.5

The general conclusion which can be drawn is that in the next decades, as far as feedstock is concerned, there will be no constraint to force the world energy supply scheme and, therefore, the world petrochemical industry to a drastic change in raw material from the present hydrocarbon basis.

The situation of the possible alternative feedstocks, mainly coal and biomass, should be assessed separately for global and for local cases.

Alternative feedstocks for the petrochemical industry are available and the corresponding commercial processes exist to produce primary petrochemicals from these. Several industrial-scale plants are in operation around the world. Research is going on and new developments will certainly surface. The main obstacle to a world-wide competition from these alternatives lies in economics; they are inherently more expensive, both in investment and operation. In the case of coal the following main reasons prevail:

(a) Besides carbon, hydrocarbons also contain hydrogen. Coal contains much less or none. Hydrocarbons from coal need hydrogen production (also from coal) and its introduction into the molecules.

19/ Energy in profile, Shell Briefing Serive, Number Five, 1984.

(b) The handling of solids in big quantities requires high investments and is a costly operation while liquids or gas can be transported by pipelines which is a less expensive way. New techniques, such as shipping solids in slurries by pipes can diminish the difference but not eliminate it.

(c) Efficiency with solids is necessarily lower in any chemical process than with liquids. Specific consumption figures are, therefore, higher and yields lower when solid fuels are used.

For the biomass sources, the economic drawbacks are similar, although the causes are somewhat different. The costs of raw material collection and transport and the logistic difficulties on the input side, together with low concentration of the products due to the biological processes, are the main causes of higher costs today.

These disadvantages can only be compensated by a relatively lower price for coal or biomass. On a world-wide basis, with the possible new processes entering in the next decade, differences in the production costs will probably remain in favour of the hydrocarbons.

The assumptions of a constant rise of crude oil prices generally adopted in the early 1980s proved to be wrong. Crude oil prices respond very easily to market conditions since in contrast to coal or nuclear energy, its production cost is only a minor part of the price, viz. around 15 per cent of the consumer price for the cheapest and under 50 per cent even for the most expensive crude. The remainder are mainly producer and consumer government revenues. Should the alternative feedstocks became more cost efficient, oil has a very large margin to follow suite.

Local conditions, however, can be quite different. While in countries having access to sufficient quantities of hydrocarbons, there is and will be no reason to base the fuel supply, and hence the petrochemical industry, on an alternative feedstock, in other countries without such resources the situation can be different. Local economic and political conditions could be such that the advantages of utilizing local resources can compensate for the economic disadvantages of the production. In any case, be it coal or biomass and

whichever process route is chosen, the main problem to be solved will be fuel production while petrochemical feedstock will play only a secondary role. Brazil, an example of alternative feedstock utilization, demonstrates this clearly.

In Brazil, the biomass utilization, i.e. ethanol from sugar cane has been the big nation-wide project to solve, at least partly, the motor fuel problem, but the petrochemical industry is still based mainly on the hydrocarbons coming from the processing of local or imported hydrocarbons.

Reverting to the global situation, it can be seen that hydrocarbons will remain the dominant feedstock for the petrochemical industry. However, among hydrocarbons there is already a shift in course and it will prevail in the next decades, away from naphtha towards lighter and heavier hydrocarbons.

World motorization shows a constant upward trend and with it the motor fuel consumption although at a slower pace due to smaller cars and more efficient engines. The world crude oil production is shifting towards the heavier quality yielding less light fractions. Coal, natural gas and other energy resources replace the heating oils more and more.

The refineries go over to complex operations converting the maximum of the heavy fractions to light products.

Associated gases and other new fields yield natural gases relatively rich in ethane and LPG in growing quantities.

This situation allows the following conclusion on the effects of the feedstock on the future development of this industry.

Naphtha which is today globally the main feedstock both for olefin and aromatic production will not lose its leading role but its share will diminish constantly in favour of other hydrocarbons, both heavier and lighter than naphtha. Ethane is an obvious choice wherever it is available and its role will be predominant in the Middle East, declining in the United States, but in Europe it will somewhat expand. LPG is a very favourable alternative but its

utilization will depend on its price; although available in relatively big quantities, many other users will compete for it. Fuel oil and other heavy fractions are more expensive to process, as far as both investment and operation are concerned, so the price relationship will decide the share they can acquire.

The feedstock situation is, therefore, favourable for the developing countries having hydrocarbon resources for the development of a domestic petrochemical industry. For those who have none, local conditions and government policies will decide on the opportunity and economic viability of the utilization of alternative feedstocks for the development of their petrochemistry.

Seen globally, it seems that from the feedstock side nothing prevents the petrochemical industry to resume its place among the high growth sectors, at least for the next fifteen years.

3.4 Technology

3.4.1 Research and development. Its role and place

It is widely recognized that the key factor, responsible for the petrochemical industry's remarkable resilience and adaptability to changed circumstances is technology and its prerequisite, research and development.

One single example, but characteristic for the technical innovation which helped this industry to recover from the difficulties caused by the oil price shocks was chosen from the ethylene production. Figure 15 shows the dramatic drop in specific energy consumption (from around 18 MBTU/lb to 5 MBTU/lb) and the rise in yields (figure 16 and 17)[20/].

The results of the ongoing research efforts will decide if this industry will gain a new impetus or will slowly join the group of really mature industries.

20/ How can the olefins industry survive in the 1980s, CEP, February 1984.

Figure 15. Reduced energy consumption

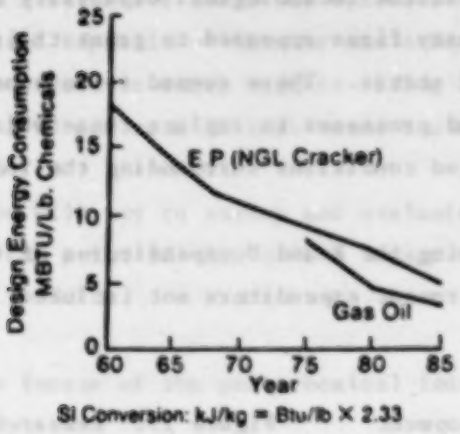


Figure 16. Yields improved by design advances

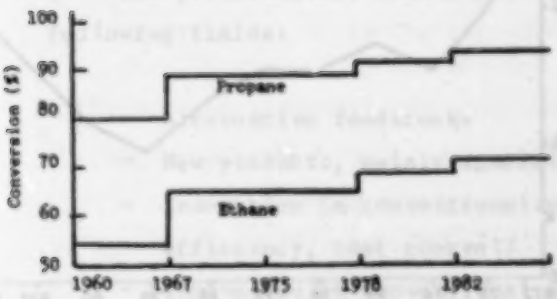
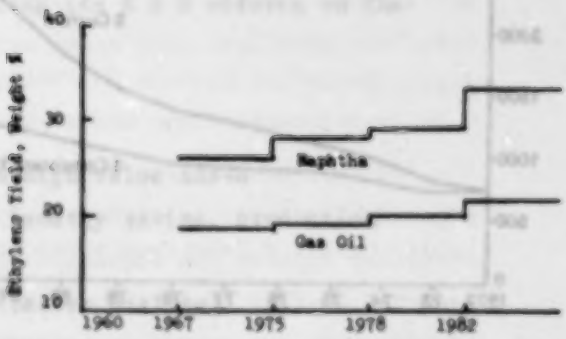


Figure 17. Yields improved by design advances



Prior to 1980, some doubt existed about the future of petrochemicals. The consensus of opinion was that prospects for its future growth were severely limited, both because of the saturation of the markets by many of its derivatives and because of the feedstock cost advantage of any Middle East oil producer who cared to engage in downstream development. It was recognized that investment in new plant just added to the overcapacity already existing in Europe, since most of the economies of scale, attainable from ever larger production facilities, had been achieved.

The apparently sudden maturity of a number of commodity type products of the chemicals industry - plastics, fibres, dyestuffs, for example - resulted in a great deal of concern about the technological capability of this former giant of innovation. Hence, many firms appeared to grant their research and development functions a higher status. There seemed to be a new urgency to the search for new products and processes to replace those which had ceased to be competitive under the changed conditions surrounding the industry.

Figures 18 and 19[21/] showing the R and D expenditures of the United States chemical industry, government expenditure not included, demonstrate this new trend.

Figure 18. Research and development expenditure by the United States chemicals industry (million $US)

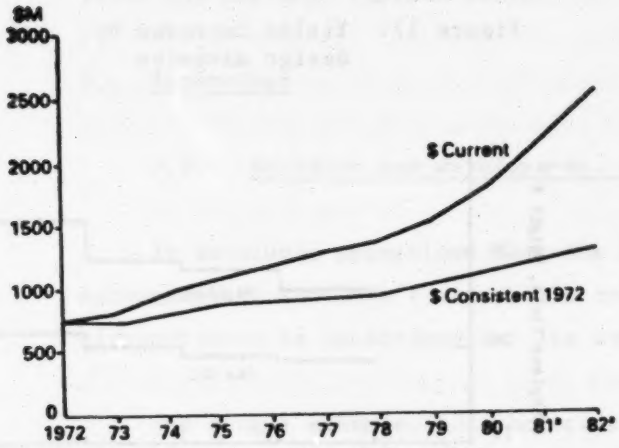


Figure 19. Research and development expenditure as a percentage of sales, by the United States chemicals industry (per cent)

Thus, the extensive research and development activity which characterized the petrochemical industry in the days of high growth rates, before the oil crisis, did not follow the downward trend of the production. As in all problem sectors, governments and companies equally recognized the great assistance R & D activity can lend to such difficult situations by opening ways for new and cheaper raw materials, developing new and better processes and products with higher profitability.

21/ John R. Anchor: Managerial Perceptions of R and D in the United Kingdom Chemical Industry, Part 3. Chemistry and Industry, 5 August 1985.

This was the case with the petrochemistry, too. The development effort in this directions was first maintained and later reinforced. Big government participation in alternative feedstock utilization research in the United States, the Federal Republic of Germany and other industrialized countries in the 1970s and corporate research budgets rising 50-75 per cent in current money terms and 5-10 per cent in real terms could be observed.[22/]

This section will try to survey and evaluate the research and development activities from the point of view of the impact that foreseeable new results can have:

(a) On the future of the petrochemical industry, its development trends and speed;

(b) On the projects to be realized in the developing countries.[23/]

3.4.2 Fields of research

The petrochemical industry is concentrating its R & D efforts on the following fields:

- Alternative feedstocks
- New products, mainly specialties with high value added
- Innovation in conventional processes (energy saving, production efficiency, cost control)
- Innovation in conventional products (better quality)
- Development of new product applications.

Research on new processes is going on, but represents only a minor part of the R & D budgets.

22/ Market Trends for Chemical Products 1975-1990 and Prospects to 1990, ECE/Chem/40, Vol. I.

23/ A detailed survey of the R & D activity can be found in the study: Projections of R & D Trends in the Petrochemical Industry: Possible Impact on Production Structure in Developing Countries by the Year 1990, UNIDO/IS. (forthcoming).

An interesting and typical example is that of Du Pont.[24/] The company spends two thirds of its chemical R & D budget on product research, i.e. 35 per cent on new product development and 32 per cent on product improvement. The remainder is spent on process work, viz. 23 per cent of the total budget is devoted to process improvement, 7 per cent to new process development and 3 per cent to capacity increase.

Alternative raw materials

In the 1970s the hydrocarbon supply situation appeared critical and most industrialized countries spent large sums on research to find alternative feedstocks, mainly for energy purposes.[25/] This tendency has subsided today and the United States Government only sponsors such projects where the interested companies are willing to take over at least half of the costs.

Gasification of solid fossil fuels

The main activity has been concentrated on the gasification of fossil solid fuels, mainly coal, to produce a synthesis gas mixture. The relevant processes have been well known since the 1930s and proven on an industrial scale.

Further development work underway is aiming at gasification, at higher pressures, as well as at better efficiency. Results in both directions will certainly improve the economics of these processes but no real breakthrough is expected in this time period. Developing countries interested in coal gasification can expect several commercially proven medium-pressure (30-100 bar) processes by the 1990s which, in given local conditions, might be put to use with a fair chance of economic viability.

24/ How Du Pont spends its $1.1 billion budget (Chemical News), 31 July 1985.

25/ Emerging Energy and Chemical Applications of Methanol: Opportunities for Developing Countries. The World Bank, 1982.

Biomass utilization

Biomass as raw material for the petrochemical industry can be processed in several ways, viz. fermentation, gasification, pyrolysis, hydroprocessing and other chemical methods.

Fermentation is the oldest and best known route for both end products, alcohol and methane. Alcohol, a good starting material for petrochemicals, once the main source for ethylene production, has been produced from sugar since the earliest days of mankind. Today, this process is used on a big industrial scale to provide alcohol for motor fuel purposes. The existing process technology, however, works only with sugar and in a diluted solution. A high volume of equipment and big quantities of heat energy, although provided in most cases by burning the plant residues, e.g. sugar cane, are necessary for a concentrated end product. R & D work is underway in different directions:

(a) To improve the efficiency of the process by microbiological methods, i.e. strains working in more concentrated media;

(b) To use other, cheaper raw materials such as starch, cellulose without prior chemical treatment, but processed by biological means only, or by steam treatment;

(c) To improve the economics of the process by engineering methods such as new separation techniques, etc.

Although in the microbiological fields surprises and even revolutionary new results are rather the rule, even a major breakthrough in this field would need a decade for commercialization and general acceptance.

Methane by fermentation of waste organic matter is also a well known process but it is of limited use. It is excellent for fuel production on a small scale for local needs, but it can hardly serve as industrial feedstock. Research work is not extensive in this field.

Gasification of organic matters is also an important method for producing fuel gas on a relatively small scale for local purposes but not for providing petrochemical feedstock.

An interesting development in this field is a variant of the well known oxo-synthesis used in the production of the so-called oxo-alcohols for plasticiser production. Hydrolysis of wood or crop residues gives sugar, while the organic by-product is gasified to a CO-rich mixture. By a complex and interlinked series of reactions from the sugar and the CO-rich gas, vinylacetate or ethylacetate can be produced.

Pyrolysis of organic matters, e.g. charcoal from wood, is also a very old process route but not well suited to further development, as it reduces rather than increases the H/C ratio of the liquid products.

Hydro-processing is the common name for different processes. These include the treatment of the feedstock in a hydrogen-rich atmosphere, under medium to high pressure, hydrocracking i.e. breaking the heavy molecules into small ones, hydro-dealkylation, elimination of the side chains from aromatics, and others. Hydro-dealkylation is one of the most promising developments, because it increases the H/C ratio at the expense of the undesirable O/C ratio using external hydrogen. The raw material can be any agricultural waste or by-product and will give a liquid hydrocarbon mixture which can be processed for conventional motor fuel. Even lignin, a by-product available in large quantities from cellulose manufacturing, could be used to produce aromatics through one of the processes in development.

Developing countries with agricultural by-product resources should follow the results of the above R & D work closely but wait for commercialization of the new processes before adapting them. The probability is high that new processes emerge which would be industrially viable.

Primary petrochemicals

Most of the R & D activity in the production of olefins and aromatics is oriented towards process improvement and feedstock versatility. Development results will yield better efficiencies, higher yields, less investment and a broader choice of feedstock, but no new processes or major changes are in view. Even for the alternative feedstocks, e.g. ethanol, commercially proven processes are available.

For the syngas production, adequate processes are available for hydrocarbon feedstocks. These will be constantly improved but no major changes are expected. Alternative feedstocks need further intensive R & D which is going on. The resulting improved and commercially proven processes could open new possibilities for developing countries without adequate hydrocarbon resources to base their syngas production and processing on domestic raw materials.

Intermediates

Not only are the compounds almost limitless in number but the different fields are also very numerous. R & D is going on in every field and results will certainly not be lacking. In this study, however, it is necessary to limit the field covered to the two items considered the most important for the developing countries, viz. C_1 and C_4 chemistry.

(a) C_1 chemistry. The most interesting and promising field in this respect is the C_1 chemistry. This means the building up of different compounds containing several carbon atoms from a simple one containing only one carbon atom, methane, CO or methanol. Methane is a feedstock, CO is one of the main constituents of the syngas, a primary product and methanol is an intermediate product manufactured from syngas, possibly from non-methane feedstock. A whole spectrum of products can be made from the C_1 compounds, such as olefins, aromatics, synfuel, acetic acid, oxo alcohols etc. and all their derivatives. Direct and indirect routes are intensively researched.

Some processes are already commercialized, others are emerging now and more can be expected. Catalyst chemistry is playing and will play a decisive role in the developments of this field.

Developing countries with no liquid hydrocarbon resources could be interested in the results which are realistically expected from the research in this field and industrial realization can be taken into consideration for the 1990s.

(b) C_4 chemistry. The hydrocarbons with four carbon atoms form an important part of the product spectrum of the steam cracking and different refinery operations yield also C_4 compounds. Butadiene is well known for its use in the production of synthetic rubber. Isobutene has recently found wide utilization in the production of MBTE, an octane number enhancing additive, particularly important in lead-free gasoline production. Intensive research is going on in view of better separation and isomerization processes for this fraction and for the better valorization of the different other components (1-butene, etc.). New achievements will probably emerge in the next few years, with commercial application to follow immediately, as usual. Developing countries expected to have C_4 fractions will, therefore, be able to incorporate the results of the ongoing R & D activity in their projects for the 1990s.

End products

Although the researchers have not lost interest in the synthetic rubber technology, innovation processes are directed mainly at plastics and fibres. New monomers and new polymers are presented regularly. The development tends to gain momentum. It can be presumed that this tendency will prevail in the next decade. The improvement of the existing processes and products will nevertheless keep pace with the development of new processes and products. The new plastics and fibres are and probably will be more of the specialty type intended for the nuclear, electronic, space and other high technology industries.

It is very difficult to forecast the market size for the new products. However, Du Pont alone expects to commit nearly $5 billion in specialty polymers by the year 2000 and hopes to open markets in:

- Electronics with a total sales volume of $400 billion/year by 1990.

- Packaging. The plastic consumption is at present $0.7 billion, but it can be raised 5-10 fold.

- Auto plastics. Plastics are now around 7 per cent of the weight of non-structural auto parts. This can be tripled by the late 1990s.

- Membranes with a total sales volume of $US 2.4 billion/year by 1990.

- Aircraft and aerospace (composite materials) with a total sales volume of $10 billion by the late 1990s.

3.4.3 Conclusions

The above optimistic view is concluded with the following: "We are on the fore front of emerging technologies and we expect this to provide a future of high growth".[26/]

These views can be considered as over optimistic, but most specialists agree that the slowdown in new products and processes in the immediate past is not a sign of complete maturity for the whole industry but only for the high volume commodity products and that the industry will shortly regain the point of technological innovation and with it its growth trend above the industrial average.

26/ R.C. Forney, Executive Vice-President, R & D, Du Pont, quoted in Chemical Week, July 31, 1985,.

This would mean a gradual shift of the commodity, high volume end products to the developing countries, while the new, high technology products will make their first appearance and inroads in the industrialized countries.

Developing countries will be most interested in the improvements in processes and products currently used. Their plans for the next decade will probably not be influenced by the new results but when a new investment is decided in this field, the latest developments should be known and considered.

3.5 Restructuring

The restructuring process in the world petrochemical industry started in the mid-1970s, intensified at the beginning of the 1980s and will continue for the years ahead. This restructuring takes place in three different but interrelated dimensions: organizational, technical and geographical.

This process has been and will be a major factor in the relative development of the petrochemical industry in the different regions but is indirectly influenced and will itself influence the global petrochemical trends, too. It is necessary, therefore, to investigate this process, its origin, the forces, the obstacles and contraints encountered; to deduce the possible development trends and assess their effect in the global and regional development of the petrochemical sector.

3.5.1 Organizational restructuring

Petrochemical companies reacted to the prolonged recession, the low capacity utilization and inadequate economic returns not only by capacity reduction, i.e. only closing down or idling plants but restructuring of the whole international sector is also underway. The three most characteristic features of this restructuring can be summarized as follows:

(a) The giant oil companies' forward integration in petrochemicals. This process started in the 1960s, accelerated in the 1970s, but slowed down in the 1980s due to the prolongation of the recession, the slack oil market and the erosion of the cash surpluses of the oil companies. This integration

is still going on. Commodity plastics production of the oil companies rose by 17 per cent against 3 per cent of that of the traditional Western European chemical companies between 1975 and 1982.

(b) The big chemical companies' main thrust is directed towards the specialty, high value-added petrochemicals, such as engineering plastics, industrial fibres, etc., abandoning slowly their dominant position in the bulk, lower value-added products. This is clear not only from the production figures, but much more from the R & D activity. The backward integration of the chemical firms into refining, which was also a marked tendency in the 1970s, was represented only by a few examples (e.g. Du Pont/Conoco), mainly in the United States.

(c) The reorganization of the whole industry is underway, both at coporate and inter-corporate levels. Huge mergers in the United States of America, nationalizations in Western Europe and direct government regulations in Japan tend to get rid not only of the redundant plant capacities but also of the redundant industrial structures, organizations and administrations.

At the corporate level, huge reorganizations have been undertaken, stream-lining all the services and production units. Production profile exchanges between companies were frequent. Such reorganizations occurred on a big scale in France but nearly everywhere similar movements take place.

3.5.2 Technical restructuring

As discussed in detail in section 3.3 above, no fundamental switch-over to non-hydrocarbon feedstocks will occur in the next ten years. The feedstock situation, however, will constantly undergo important modifications. The share of naphtha will diminish, natural gas and LPG on the one hand and heavier fractions on the other hand will have a growing role. Both changes have a great impact on the structure of the whole petrochemical industry. Lighter feedstocks (ethane from natural gas and LPG) give less propylene and butylene- butadiene by-products, while heavier ones lead to more of these by-products. Although the growing share of gasoline among the petroleum products provides an outlet and utilization of propylene and other heavier

by-products for gasoline blending components, the change of the feedstock pattern will also bring about corresponding modification in the intermediate and end product distribution. The direction of the change is hard to forecast, since both lighter and heavier feedstock will be available. The first will come from the natural gas resources in Canada, the North Sea and the Middle East, the latter from the crude processing. For both there will be competitive users and the prevailing relative price situation will decide the direction of the change.

3.5.3 Geographical restructuring

Until the 1970s, the petrochemical industry followed the geographical structure of petroleum processing. It processed the hydrocarbons made available in the three main industrialized regions, United States, Western Europe, Japan. The end products were consumed mainly in the industrialized countries but there was a growing export to the developing countries. For example, in 1975, developing countries accounted for 8 per cent of the world consumption of basic petrochemicals and 15 per cent of that of end products, but they produced only half of the amount they consumed. During the period between 1975 and 1981, production and consumption growth was much faster in developing countries. More than 100 per cent as compared to 50 per cent world average. This tendency was reinforced in the period from 1981 to 1983.

This geographical restructuring process is dictated by the following factors:

(a) Due to the slowness of economic recovery, consumer demand was low and substantial overcapacity existed, mainly in the industrialized countries. Many of these plants are over 10, 15 or even 20 years old.

(b) Developing countries with abundant hydrocarbon resources build up their own petrochemical industry for one or more of the following reasons: (i) to utilize the resources wasted until now (gas flared); (ii) to valorize their primary resources, and (iii) to improve the economics of the hydrocarbon processing on site.

(c) Developing countries with broad markets, even without adequate hydrocarbon sources, are forced in many cases to create, at least partly, a domestic petrochemical industry, starting with end-products. By reducing the volume of petrochemical imports they can improve their foreign currency balance.

The overall picture shows a slow general growth as a result of new plants starting, mostly in developing countries and old plants closing, nearly exclusively in industrialized countries. Both factors work in the same direction: the share of the developing countries rises steadily.

Table 5 gives an approximate picture of the plants closed or idled in the United States, Western Europe and Japan between 1981 and 1983. In Western Europe, e.g. 26 per cent of the ethylene, 18 per cent of HDPE, 17 per cent of polystyrene and 14 per cent of the PVC capacities were closed down. Table 6 shows some of the deferred or suspended petrochemical projectsin the developing countries.

Will and can this trend be sustained or even accelerated? Figure 20 shows the world trade of crude and ethylene derivatives by the end of this decade, based on projects planned for the 1975-1990 period[27/] as seen by the ECE. A good part of the basic petrochemical production will shift from the industrialized countries to the oil-producing developing countries and with it the manufacturing of the bulk intermediates and some end-products. Japan, a net exporter, will become a net importer as will Western Europe, while the Middle East and Canada will emerge as great exporters. The industrialized countries, besides their participation in the new ventures in the developing countries, will concentrate in their home industry on specialty products like engineering plastics and fibres for the aerospace, electronics, computer and nuclear industry.[28/] This restructuring process calls for mutual

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27/ The Role and Place of the Chemical Industry in the Economies of ECE Member Countries (ECE/CHEM/48), 29 March 1985.

28/ Ibid., page 11.

understanding and close collaboration both North-South and South-South, in technology transfer, market organization, R & D, long-term planning and joint-ventures.

This will not be an easy process for the next five years and even less easy for the period afterwards. Two main problems will, among others, certainly constitute restraints limiting this trend, viz. the financial and commercial problems.

Table 5. Capacity reductions in the United States, Western Europe and Japan, 1980-1983[a/]

	Plant closures		Plant idling
	Thousands tpa	Per cent of total capacity	Thousands tpa
Ethylene			
United States	1,700	100	3,800
Western Europe	3,570	21	250
Japan	2,250[a/]	36	520
Total	7,520		4,570
PVC			
United States	200	6	500[b/]
Western Europe	860	14	
Japan	490[a/]	24	
Total	1,550		
LDPE			
United States	830	21	
Western Europe	1,820	27	
Japan	270[a/]		
Total	2,920		

a/ The plant closure figures for Japan include the planned closures up to August 1985.

b/ Postponed.

Source: World changes in the structure of the petrochemical industry, 1980-1983, UNIDO Expert Group Meeting on International Co-operation on Petrochemicals, Vienna, 19-21 September 1984.

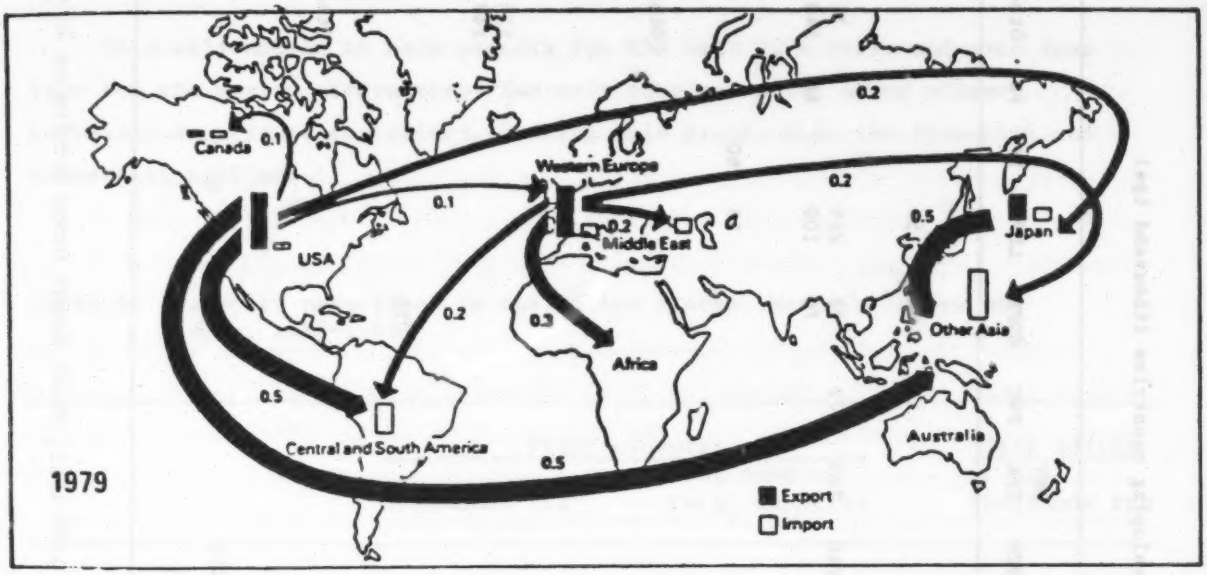
Table 6. Deferred or suspended petrochemical plant construction in developing countries (thousand tpa)

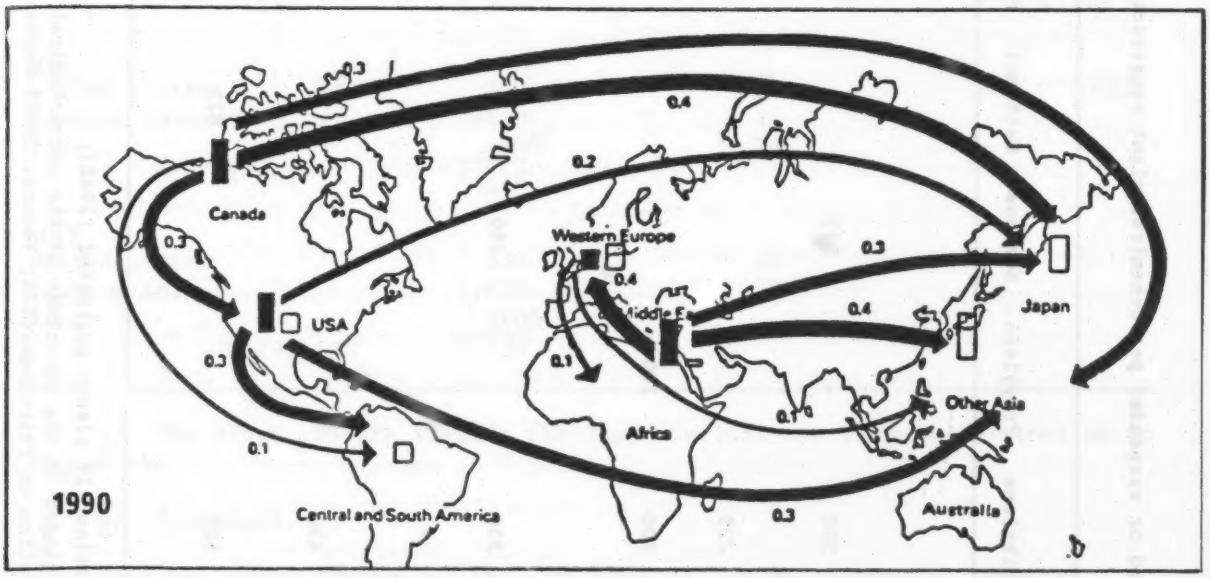
Countries (causes)	Ethylene	Propylene	Benzene	Methanol	Styrene	VCM	DMT TPA	PVC	HDPE	LDPE	PP	PS	Other
Lybian Arab Jamahirya (debt)										55			
Indonesia (declining oil sales/prices)	350	-	375			240	225	72	70 70	215 100		68	71 EG 148 Xylene
Philippines (debt)	225									55	60		
Algeria (declining oil sales/prices and long-term arrangements)	500	200			200								Others
Kuwait (long-term arrangements)	350		280		339								135 EG 147 Xylene
Qatar (feedstock)									70				
United Arab Emirates (feedstock)	450												Others
Mexico a/ (declining oil sales/prices)	500			825		300							

a/ Laguna del Ostion, 19 plants postponed (1988).

Source: World changes in the structure of the petrochemical industry, 1980-1983, UNIDO Expert Group Meeting on International Co-operation on Petrochemicals, Vienna, 19-21 September 1984.

Figure 20. Possible trade flows for ethylene derivatives in 1990, compared with 1979





3.6 Financial constraints

Geographical restructuring goes on mainly by building new plants in hydrocarbon rich and in the main consumer areas. Investment activity is flourishing when the projects are profitable and capital is available so the cost structure, the competitiveness and the capital market will play a major role in this field. Therefore the cost structure should be investigated first. The two main cost factors deciding on the competitiveness of a project and where the major differences between industrialized and developing countries occur, are the capital-related costs and the feedstock costs. Therefore in the following section on the role of these two factors will be researched.

3.6.1 Cost structure

Production costs

In order to present the cost structure and the effect of the main cost factors on the production cost, a few representative petrochemical products were selected. Table 7 gives their cost structure. The primary products, ethylene, both from naphtha and ethane, the intermediates, caprolactame and acrylonitrile, the end products, low density polyethylene (LDPE) and polyvinylchloride (PVC) and one fibre, Nylon 6, are presented.

Capital costs for the capacities considered (lines 1-5) and production costs (lines 6-12) for European sites (1980 prices) were taken in the usual way.[29/] The main factors are obviously the raw material and capital related costs. Neither of them, however can be directly seen from the table. Raw material costs as shown against line 6 are often misleading because of the by-products (e.g. ethylene from naphtha). Deducting the by-product credit from the raw material costs would distort the picture considerably. Taking into account the total production costs is also only an approximation. Although this is not the true solution, the quantity of all products with the price relationship should be considered, the error is not significant.

29/ CHEM SYST DATA.

Table 7. Cost structure of some representative petrochemicals (West European site, 1980 prices)

			Ethylene from naphtha	Ethylene from ethane	LDPE	PVC	Caprolactane	Acrylonitrile	Nylon 6
1	Production 1000 MT/year		450	450	120	90	80	272	12,5
2	Battery limit capital cost	MM$	320	215	57	35	114	89	8
3	Offsites capital cost	MM$	128	86	39	15	51	43	3
4	Total fixed capital cost	MM$	448	301	96	50	165	132	11
5	Working capital	MM$	202	64	40	25	46	68	9
6	Raw material cost	$/MT	1,122	273	774	659	1,158	685	1,896
7	Utilities	$/MT	163	109	60	55	314	20	52
8	Operational costs	$/MT	30	21	26	23	70	21	41
9	Overheads	$/MT	166	96	129	102	314	87	190
10	Total of (6 + 7 + 8 + 9)	$/MT	1,481	499	989	839	1,856	813	2,179
11	By-product credit	$/MT	-807	-71	-	-	-123	-66	-
12	Net production cost	$/MT	674	426	989	839	1,733	747	2,189
13	Return on investment (10%)	$/MT	100	67	80	56	207	48	84
14	Raw material cost Case A	%	71	48	72	74	56	80	84
15	Raw material cost Case B	%	67	44	67	69	51	75	81
16	Capital related costs Case A	%	18	31	20	18	26	16	12
17	Capital related costs Case B	%	23	38	26	23	33	20	15

Therefore, when calculating the percentage of the raw material costs in the total costs, the figure in line 6 was divided by the sum of line 10 and 13, return on investment (ROI), and multiplied by 100. The figure in line 13 corresponds to a 10 per cent return on investment. Line 14 gives the percentage of raw material costs with 10 per cent ROI (case A), while line 15 was calculated with 20 per cent ROI (double of the figure in line 13, case B).

The capital related cost calculation basis is summed up in table 8.

Table 8. Capital cost related factors

	Battery limit investment (percentage)	Offsite investment (percentage)	Working capital (percentage)
Depreciation	10	5	0
Maintenance	6	3	0
Interest	0	0	10
ROI Case A	10	10	0
ROI Case B	20	20	0

$$\text{Capital related cost \%} = \frac{\dfrac{(\text{BLCC})\ 0.16 + (\text{OFF})\ 0.08 + (\text{WORK})\ 0.1}{\text{Production}} + \text{ROI}}{\text{Total of } (6 + 7 + 8 + 9) + \text{ROI}} \cdot 100$$

Case A = ROI 10%

Case B = ROI 20%

Raw material costs make up half to 80 per cent of the total costs, while capital related costs vary between 12 and 38 per cent.

Investment costs in the developing countries are higher than in the industrialized ones, for the reasons mentioned in the Second World-wide Study[30/], where the corresponding factors are also estimated. This constitutes a handicap for the developing countries, raising the capital related costs in the production. In several cases, they have to compete against factories with fully depreciated investment. On the other hand, raw material prices can be lower than the world market ones and this could compensate the capital cost handicap, since the weight of the raw material costs is roughly double that of the capital related costs. In factory gate production costs, the developing countries having domestic resources can, therefore, be competitive.

The competitive advantage of the hydrocarbon-rich countries is very controversial. Some studies estimate that ethylene can be produced in such sites at nearly half of the cost as e.g. in the United States.[31/] These estimates are based on a fuel price of $US 0.25/MMBTU (a rather uncommon figure) against $US 4/MMBTU in the United States. More cautious authors,[32/] underline that this advantage is gradually eroded with every further processing step. So the same calculation, when LLDPE is the product, arrives at a 20-25 per cent advantage, which is still considerable.

In any event it can be concluded that in factory gate prices of petrochemical products the hydrocarbon-rich developing countries have an advantageous position and the production costs will therefore not present any limitation to this restructuring.

Passing from the factory gate costs to the market place costs, two distinct aspects have to considered:

30/ Second World-wide Study on the Petrochemical Industry: Process of Restructuring (ID/WG 336/3, page 120).

31/ N. Dabdad, B. Mohynoldin, Oil based and non oil based industrial development in the Arab Gulf Region (Drha Ctoic, 1982).

32/ C.H. Steinbaum, The petrochemical industry: a worldwide scenario for the '90s. Chem Systems.

- Domestic market
- Export market.

In the domestic market, competing imported goods have the double disadvantage of tariffs and transport costs with marketing and distribution costs supposed to be equal. Therefore local production cost somewhat above the world market price could still allow competitive operation. This means that for countries having no cheap and abundant hydrocarbon resources but big internal markets, local production costs, even up to a certain limit above the world market level, can be attractive enough and up to this level, this factor will not be limiting the expansion of a domestic petrochemical production.

When exporting, the reverse is true. The domestic production costs advantage should compensate for the transport and tariff expenditures. This competitive price can be arrived at either by being content with a smaller ROI or by setting the raw material prices lower than the world market level. Since a low ROI will not attract capital under the present circumstances, a better policy would be to benefit from the industrial operation in form of profits and thereby making full use of the competitive advantages in the raw material situation rather than selling the raw material to the petrochemical company at higher prices.

Thus the hydrocarbon-rich countries can profitably expand their export oriented manufacturing capabilities by accepting prices sufficiently below the world market ones for the feedstocks (opportunity prices) to keep the products on the markets competitive. In this case cost and profitability will not be constraints.

3.6.2 Investment cost

The tight credit situation of the developing countries and the high demand for capital in the general industrialization process makes the question of the investment costs particularly important. Petrochemical investments have some inherent disadvantage. High capital costs create a small number of jobs, high technology and sophisticated automation cannot be replaced by manual or less advanced ones. From the 1960s to the late 1970s the price

level of the petrochemical projects rose faster than the general inflation and even the general trend of the capital goods. This was due to the high demand for the sophisticated know-how and equipment necessary to build huge petrochemical plants. It seems that the slackening of the demand can reverse this trend and reorient the price level curve to follow the general capital goods price development pattern. Investment can thereby become more attractive. The indications for such a pattern are clear[33/] but need to be confirmed as a general trend.

3.6.3 Investment capital

Even when petrochemical investment costs follow the general trend, development will always demand huge investments. This is a limiting factor and a constraint for the development in every developing country, although to a different degree. The gradual erosion of the oil revenues and the development of the balance of current accounts are the cause that even in the rich countries, investment had to be restricted, as several cancelled or postponed projects demonstrate (table 6).

The debt situation in many developing countries is such that even for the most profitable investments only limited amounts of loans can be secured.

Equity capital participation from the leading petrochemical companies can alleviate, but not wholly eliminate this problem.

The conclusion is, therefore, that cost factors will not be limiting, but on the contrary, capital outlay will be one of the main constraints for the development of the petrochemical industry in the developing countries and thus for a geographical restructuring.

33/ W. Lavers, Factors affecting the world fertilizer industry to the year 2000 and beyond, Seminar on Trends and Development in the Fertilizer Industry, Istambul, Turkey, 13-17 May 1985, ECE CHEM/SEM.14/3, p. 25.

3.7 Marketing constraints

Major developments of the petrochemical industry in the developing countries will have their impact on the world market and conversely, the world market situation and the price development will profoundly affect the economic viability of the next petrochemical ventures. With the current overcapacity situation, even the projects serving the internal market only will replace present imports, at least partly, and therefore increase the world trade imbalance. However, most of the new projects will be at least partly or temporarily export-oriented. In the next decade, the problems of marketing will perhaps be more difficult and more important for the developing countries than all others such as technology, skilled manpower, infrastructure etc.

It seems therefore appropriate to:

(a) Consider logistics of the international trade movements, both from the technical and economic points of view;

(b) Review the marketing methods and commercial practices in the world market of petrochemicals;

(c) Consider the main obstacles the developing countries will have to overcome when entering the petrochemical market; and

(d) Identify the possible marketing strategies and methods and their applicability for the developing countries.

Annex 3 presents an analysis of the first three points, while point (d) is treated in chapter 6. The conclusions from annex 3 can be summarized as follows:

(a) Adequate logistic systems necessary for the exportation of big quantities of petrochemicals from emerging producers in developing countries do not exist at the moment. Their creation is a prerequisite for such activity requiring huge investments, organizational work and skill.

(b) Marketing is a new field involving many multi-faceted commercial, technical and financial problems to be mastered.

(c) Tariff and non-tariff barriers can constitute a major constraint to the expansion of petrochemical manufacturing in the developing countries.

3.8 Environment protection

In our environment and safety conscious world of today and tomorrow, it is of interest to have a look at the possible impact of these problems on the future of the petrochemical industry.

The very nature of the petrochemical industry is directed at safety minded process development. The highly inflammable, often explosive, hazardous and even poisonous materials handled in huge quantities and under extreme conditions (pressure, temperature, composition etc.) imposed the maximum of safety measures possible. Threfore a high degree of instrumentation and automation was always one of the main characteristic features of this industry. The record of this branch, in spite of very few spectacular and widely published accidents, is extremely good. All accident rates, related to the number of working hours accomplished or to the product value, place it among the safest, in spite of the above-mentioned real hazards involved.

In some other industrial branches it is possible to consider whether a lower degree of mechanization and automation is better suited to the conditions in some developing countries creating more jobs needing less investment cost and causing less operational problems. In the petrochemical industry in any country the process conditions impose the maximum of automation for safety reasons.

The situation is different in the pollution field. In the early days of this industry, feedstocks and products were all relatively cheap. The whole industry and society in general was much less environment protection-minded. So polluting materials emitted with both gaseous and liquid effluent streams as well as wastes of any kind received less attention and care. In the last

quarter of the century the situation has changed drastically. Pollution control became a social and economic necessity. New plants are designed and built to conform to strict rules and regulations and most old plants have also been retrofitted with the necessary pollution abatement systems. The necessary investments are costly, usually 5 per cent of the total project cost has to be spent on these items, but the overall economies are better. In most cases the recovery of the materials wasted in former times can cover at least part of the expenses. In some cases the whole operation can even be profit making. A study prepared by UNIDO[34/] describes in detail the pollution control problems and their solution in the petrochemical industry. Here only the main conclusions are recapitulated:

(a) Developing countries should not be regarded as places where eventually less stringent rules and regulations would allow a neglect of the pollution control requirements.

(b) First and of utmost importance is the process design. It must provide to the maximum extent possible for the elimination or at least for the minimization of pollutants. This is the most effective and a less costly way of environmental protection.

(c) Effluents and wastes which cannot be avoided, should be recovered and reutilized either in the process or in the plant itself or used for other purposes to the maximum extent possible.

(d) Non-recoverable pollutants must be rendered harmless by appropriate processing methods so that effluents conform fully to the laws and regulations.

(e) Wastes must be disposed of by appropriate environment-friendly methods.

34/ Environmental study of the petrochemical industry, UNIDO/IS.568.

The actual state of the art does today allow full compliance with the enviroment protection requirements by economically justified methods. Therefore pollution problems should not have any limiting effect on the development of the petrochemical industry neither technically nor from the economic standpoint, neither in the industrialized countries nor in the developing world.

4. SCENARIOS

4.1 Introduction

The two sharp crude oil price rises and the recession considerably distorted the development of the petrochemical industry. The forecast and scenarios worked out in the 1960s and 1970s all proved to be too optimistic and the investments based on this optimistic view led to very low capacity utilization figures (60 to 70 per cent) in the early 1980s. This cast in many cases a general doubt on the utility of the whole forecasting exercise.

Nevertheless, strategies and policies have to be based on some assumptions about the future development. It is, therefore, unavoidable to work out an estimate of the future development of the industry in question. For that purpose, the first thing is to learn from past mistakes.

Two-thirds of the deviation between forecasts and actual outcome can be ascribed to the overoptimistic projections of the overall economic growth and one third to the equally overoptimistic assessment of the relationship between petrochemical and overall growth figures.[35/]

The main parameter, the general economic growth, has to be taken into account. It is clear from the data and diagrams of section 3.1, page 24-25, that the development of the petrochemical industry is tied to the general economic growth, and the GDP can be taken as variable respresenting this general economic growth. For this variable, in this study the UNITAD reference scenario was adopted.[36/] Should the actual development deviate from this reference, the petrochemical industry will follow and take a different course. For the relationship between the development of the petrochemical industry and the general scenario, several methods can be used. The simplest method is to use data for a relatively short period of time

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35/ D.R. Clair, op. cit.

36/ For an explanation see assumed GDP growth rates for the world regions as presented in "The petrochemical industry: the sector in figures", volume II of this study, section A.

(5-10 years) and, by purely statistical means, establish some sort of correlation between the growth figures of the industry in question and some general economic factors and then extrapolate this relationship to a time period equal or even longer than the basis period. This method seems unsuitable for the purpose of this study. It does not look for the technical and economic laws governing the relationship and therefore cannot give any indication of the possible effects on the casual factors. This method does not give enough insight. Therefore, instead of such extrapolations, a scenario analysis was attempted, analyzing the various factors influencing the future of the petrochemical industry, constructing a model reflecting these intrarelationships and deducing the probable ranges for the casual variables.

In this study one single scenario will be presented, but instead of a set of average figures, a range will be given, defining the upper and lower limits of the future development according to these estimates. This probability area will be supported by the maximum available information on the possible influencing factors and their estimated impact.

This scenario by itself is not based on a mathematical model using the statistical data of the past and extrapolating the trends. Although it used several forecasts made in this manner for the next ten or fifteen years and others based on other considerations, it is basically an evaluation of the actual situation. It takes into account the ongoing investment, plant closures, trade and other trends as well as other technical and economic factors influencing the development of the industry.

The scenario presented in this study is not a forecast conditioned only on historical trends in the sector but rather an outline of the likely development in a number of factors causally related to the petrochemical sector. Therefore, figures and conclusions do not necessarily coincide with the traditional economic forecasts of the sector.

4.2 Methodology

In order to work out these scenarios, a multi-faceted approach has been attempted. With the same analytical method, a two-pronged evaluation has been

tried. For the whole of the petrochemical industry as well as for the main product groups first the global then the regional development possibilities will be investigated. The product groups are:

End products: plastics
synthetic fibres
synthetic rubbers
Primary products: olefins
aromatics

Whenever possible, individual products of the above groups will also be assessed separately.

The analytical method will be the following:

First the market composition and the past trends of this market will be analyzed in order to assess its possible future development in relation to GDP growth figures. Results will then be compared to a general economic evaluation, the feedstock supply and other relevant factors and finally with each other (global versus regions and groups of regions) and brought to a coherent and consistent picture of the whole industry at the global and regional levels. The results will be presented in the form of upper and lower limit values of the estimated probability range. So in reality these values do not constitute two distinct scenarios but rather the probability boundaries of the estimated development.

The assumptions underlying this scenario will be stated wherever they occur.

4.3 Global approach

As a starting point, the following assumptions are made:

Assumption No. 1: The GDP growth will follow the trend forecast in the UNITAD reference scenario.

Assumption No. 2: No major disturbances in the global, political and economic situation will occur.

Assumption No. 3: World energy consumption will follow a steady course: for every per cent of GDP growth, the corresponding growth of energy consumption will be somewhat below one per cent. Oil supply will not be disrupted by war, embargo, or other major force. Oil prices will, in real terms, slightly decline until the mid-1990s, then rise slowly to arrive at approximately the 1985 level in 2000.

Considering the detailed analysis in sections 3.2 through 3.4 and their conclusions and by looking at the future of the main markets, the next assumption is formulated. The main markets of the petrochemical industry are all growing at a faster rate than the industrial average (transport, packaging, construction, services, electrical and electronic machines) and the relative use of most products, mainly plastics, is also rising steadily. Good examples are the accelerating application of plastics in the car industry, the substitution of metals by plastics in aerospace and electronic industries, etc. The opposite trends, relatively lower demand for tyres and partial return to natural fibres in garments, cannot by far counteract the positive influences. All these tendencies translated into figures led to the following assumption:

Assumption No. 4: The petrochemical industry will gradually recover from the effects of the two oil price rises and will regain its innovativeness. Instead of joining the fully mature industrial branches, its characteristics discussed above will allow it to reenter among the innovative leaders. A factor of 1.15 for 1985-1990 and of 1.2 for 1990-2000 means that the growth of the global petrochemical industry would have to be 1.15 and 1.2 times respectively that of the global GDP.

The above considerations, translated into figures, give a 20.2 per cent growth over the 1985 production level (3.77 per cent/year) for 1990 and 78 per cent (3.94 per cent/year) for 1990-2000.

This general assumption was checked with respect to two main product groups, end products and primary products. Intermediates as a group would be very hard or even impossible to assess in this manner because intermediates together with the process routes may change within the forecast period but the development of the primary and end products definitively determines the volume of the intermediates (table 9).

The overall growth figures for the two groups mentioned must be equal, as they are coresponding quantities. The independent variable is the end product, in its turn dependent on the market conditions.

End products

In this group, the synthetic rubbers have the bleakest prospects.

Synthetic rubber

Manufacturers of tyres and other rubber products for motor vehicles consume 60 - 70 per cent of the synthetic rubber production. Competition of natural rubber is strong although total substitution is not possible because of different properties but the ratio of natural to synthetic can be adjusted between given limits according to the market situation. New techniques, such as extrusion and casting, new materials like thermoplastics and polyurethanes threaten the quasi monopolistic position of the rubber in the tyre fabrication. On the other hand, the small volume specialty materials, among them also those for the motor industry, grew from 25 per cent of the total output in 1975 to nearly 40 per cent in 1984.

It can be supposed that non-rubber material will not make serious inroads into this territory until 1990 but developments in the following decade is doubtful. Will a real revolution take place, with new materials and techniques like the casting of polyurethanes? If the products would be better

Table 9. World petrochemical production and demand

	Estimated 1985 million tons	Factor	Compared growth rate (%)	Growth 1985-90 (%)	1990 Calc. value million tons	Lower limit million tons	Upper limit million tons	Factor	Compared growth rate (%)	Growth 1990-2000 (%)	2000 Calc. value million tons	Lower limit million tons	Upper limit million tons
End products													
Plastics[a]	45	1.25	4.1	22.2	55	50	60	1.36	4.45	54.5	85	70	90
Synthetic fibres	11	1.0	3.28	17	13	12	15	1.1	3.6	42.5	18	15	19
Synthetic rubbers	8	0.75	2.5	13	9	9	10	1.0	3.28	38	12	11	13
Others	36	1.15	3.77	20.2	43	40	45	1.2	3.94	47	63	55	70
Total end products	100	1.15	3.77	20.2	120	115[b]	125[b]	1.2	3.94	47.3	178	160[b]	185[b]
Primary products													
Olefins	74	1.22	40	21.6	90	85	95	1.24	4.07	49.0	134	125	140
Aromatics	31	1.1	3.6	18.5	36.7	35	40	1.15	3.77	44.8	13	45	55
Total primary prod.	105	1.15	3.77	20.2	126	120[b]	135[b]	1.2	3.94	47.3	187	170[b]	190[b]

a/ PE + PP + PVC + PS

b/ May not add.

or even equal to present tyres, the simplicity and ease of manufacturing would probably decide in their favour in spite of the expensive material. It seems however that for a very sophisticated and demanding application like tyres, until now only complex structures made of different materials by complex manufacturing techniques could give satisfactory products. Therefore until 1990, only rubber will be considered for these purposes, while for the last decade of this century another alternative: substitution of rubber by some of the above new material will also have to be considered.

Synthetic rubber consumption depends on new car production as well as on motor vehicle use. The recent trend has been towards lighter cars, smaller tyres and improvements in the quality of tyres, radial ply, etc., resulting in longer life. All these have reduced the demand for tyres and for rubber. It can therefore be supposed that the production of new cars and higher car use will follow the growth of the GDP, but the tyre and with it the rubber consumption will lag behind by a factor of perhaps 0.75 until 1990. The above factors, mainly the smaller weight, higher milage will be responsible for this factor, causing lower rubber consumption per unit. After this transition period, when this effect will have levelled off, the rubber consumption can follow the general economic trend by a factor of 1. So, for after 1990, it is assumed that this tendency ends and in the following decade the synthetic rubber consumption is assumed to follow the trend of the GDP. Accordingly, the production of synthetic rubber, estimated at 8 million tons in 1985 can grow at a rate of 2.5 per cent/year to 9 million tons, and with 3.25 per cent/year in the next decade to 12 million tons by 2000.

If new techniques and materials, however, gain ground, instead of a growth a great drop in demand would occur. The effects on this sector would be very serious and numerically unpredictable. Thus this scenario gives only a warning about this eventual danger. The overall effect on the petrochemical industry would, however, be small since the substituting material: polyurethane or others would be also petrochemical products.

Synthetic fibres

These have a somewhat better outlook but still not very bright. Two opposite tendencies can be observed. Demand in the industrialized countries is lagging behind the growth in GDP. The main factor is that the natural fibres are gaining ground in the garment industry and the growing use in carpets, upholstery and other industrial applications could not compensate for the losses thus incurred. On the other hand, in the developing countries the demand for synthetic fibres is growing fast, especially in the polyester field, but until now, the bulk of demand still comes from the industrialized countries. This means that on a world-wide basis the foreseeable rapid growth in the developing countries will probably just be able to counterbalance the slower pace of the industrialized countries and so the growth for the next five years will equal that of GDP. In the next decade, however, it can be expected that the effects of the intensive research activity deployed will be commercialized and new synthetic fibres as well as improved old ones with substantially better qualities and relatively lower cost will not only open new possibilities in the industrial utilization but reinforce the position of the synthetics in the garment industry. Therefore a factor of 1.1 vis-à-vis the growth in GDP, giving fibres a compound growth rate of 3.6 per cent/year and an increase by 42.5 over 10 years, was adopted. Synthetic fibre production thus would be 13 million tons in 1990 and 18 million tons in 2000.

Plastics

In this group, only the four main thermoplastics are considered (PE + PP + PVC + PS). All the others for which no suitable statistics were available are considered in the "other" group.

The market seemed penetrated already in the early 1980s for the commodity plastics. But the last two years proved the contrary and these products have shown a development above the industrial average. Nonetheless, growth has been much higher in the specialty plastics. The continuous improvement in the characteristics of the classic products, new technologies like the LLDPE process and the expanding markets in all fields (cars, transport vehicles, machines, electric equipment, agriculture, household articles and packaging)

show that the tendencies of the last few years which showed growth rates well above the industrial average are not temporary phenomena. In view of the very active R and D activity going on in this field, new processes and products can be expected in the next decade to reach commercial application. Therefore for this group of products not only a growth rate above that of the GDP, but higher than the average for the whole petrochemical industry can be supposed. So until 1990 a factor of 1.25 times the GDP growth rate was assumed giving a compound growth rate for plastics of 4.1 per cent per year and a 20.2 per cent overall production rise, resulting in 55 million tons by 1990. For the next decade, a factor of 1.36 (compound growth rate 4.45 per cent/year and a 54.5 per cent rise in production) leading to 85 million tons in 2000 was supposed. However, the relative weight of the individual plastics can change. PVC can be estimated today to have the lowest growth rate, and PP the highest. Polystyrene and PE fall in the middle. New R and D results can quickly reverse this situation. This has to be taken into account when assessing the primary product pattern.

Others

This group is most diversified. It encompasses the plastics not included in the previous groups, namely the resins, the solvents, the detergents and all the other products serving direct industrial or consumer needs. The prospective growth figures for the individual subgroups are very different. Plastics and resins (most of the engineering plastics and specialty products are included here) should exhibit the highest rate, while e.g. the solvents would just follow the GDP trend. A detailed analysis confirms that for the whole of the group the average of the end products can be applied: a factor of 1.15 and 1.20 respectively vis-à-vis the GDP growth rate for the two consecutive periods, giving figures of 43 and 64 million tons respectively.

Primary products

The development of the group as a whole must follow the trend in the end products.

The two subgroups, olefins and aromatics, show different pictures. Olefins are products of hydrocarbon cracking made exclusively for petrochemical purposes, except for a relatively small part of propylene coming from refineries and an even lesser part of butadiene manufactured by dehydrogeneration of butane. The bulk of aromatics comes from different refinery operations aimed at high octane-number motor fuels, such as reforming, catalytic-cracking etc., and only a fraction of the product is diverted to the separation plant where the BTX are produced.

Olefins

These constitute about three quarters of the total primary products and have always exhibited the highest growth rates. They are today the most versatile and important building blocks of the whole organic chemistry. Besides the classic utilization fields, plastics, aliphatic intermediates, etc., new applications like MTBE (additive for octane number enhancement) are found every day. It seems therefore justified to suppose a factor of 1.22 and 1.24 respectively for the two consecutive periods, 1985-1990 and 1990-2000 leading to 90 and 134 milion tons of production respectively. In the composition of this group, however, displacement can be foreseen.

Most of the new crackers will use lighter feedstocks such as ethane and NGL giving less propylene and butadiene. Installed capacity will be governed by the ethylene situation. The pattern of utilization, however, is going in the opposite direction. Propylene derivatives, especially polypropylene are growing much faster than those of ethylene. It can be expected that propylene from olefin plants will not be sufficient to cover the demand. In most regions today the main source of propylene is the olefin plant. Only in the United States is propylene coming from refinery operations as a by-product accounting for more than 75 per cent of the total demand. Petrochemistry, however, uses only half of this quantity, the other half is used in refineries for motor fuel purposes (polymer gasoline etc.) With regulations restricting the lead content, demand for high octane-number components will increase and refinery utilization of propylene will grow. However, should the demand

exceed the normal delivery possibilities, manufacturing processes can be adapted to produce more propylene by cracking conditions adjustment (less severe) and feedstock changes, e.g. PB utilization or fuel oil cracking.

The same tight situation can be foreseen for butadiene. There also is a solution to a possible shortage. Besides the cracking parameters and feedstock adjustments, butane dehydrogenation can also be used to a greater extent for butadiene production.

Globally it can be assumed, based on the forseeable demand analyzed above that the present ratio, 60 per cent ethylene, 32 per cent propylene and 8 per cent butadiene, will change to 57-58 per cent ethylene, 35-36 per cent propylene and 7-7.5 per cent butadiene in 1990 and to 55-56 per cent ethylene, 37-38 per cent propylene and 7-7.5 per cent butadiene in 2000.

Aromatics

The aromatics market is very complex. Not only have the different compounds completely different outlets, but most of them (except the o. and p. xylene) have so many applications that an in-depth detailed analysis would be required for a complete assessment of the development possibilities. This, however, is beyond the means and scope of this study. But a more compendious approach taking into account the fibre industry (for p. xylene), the plastic processing industry (for o. xylene), and some of the other main uses (isocyanate, a small but rapidly increasing market, intermediates, aniline, etc.) led to the assumption of a factor of 1.1 vis-à-vis the growth in GDP for the first and 1.15 for the second period.

The second check, the regional analysis will not only have to corroborate these results, but permit to deduce the missing data. Globally production and consumption should be nearly equal, but for the regions demand and production has to be estimated separately and thus trade movements, capacity utilization and investment requirements should be estimated too.

4.4 Regional analysis

An analysis of the history, actual status, feedstock and market situation, financial and technical means as well as infrastructure and logistics was undertaken separately for each region and within it for the major existing or prospective petrochemical producers and consumers in order to evaluate possible future development trends. The figures deduced in this way were compared to those of the other regions and with the total figures for the developing and for the industrialized countries and also with the global figures. Through several consecutive iterations these values become internally matched and a coherent scenario was thus developed. This scenario tries to take into account the real process governing the growth in the different regions and thus shows the marked differences in the growth rates. In some cases the forecast future trend deviates sharply from the historical development observed. For the next five years mainly the already committed or well prepared investment projects were considered while shelved or cancelled projects were disregarded. Because of this, unusually high growth rates resulted for the Middle East, where huge investments enter into production in the very near future.

The resulting scenario was based on the numerical values computed, summarized in tables 10 and 11. The data for 1985, taken as basis, were estimated from the 1983, 1984 actual data using the forecasts published during this year. The values for 1990 and 2000 are average forecasts and tend to give the relative trends among regions, but they should not be considered as effective, real numerical predictions. Since the actual development path can be different not only with regard to the relative growth of the regions but also between the different petrochemical products, no upper and lower limits were presented here. Nevertheless, one should always bear in mind that the figures are tentative average values only, with a probability range somewhat wider than the ranges given for the global figures.

Table 10. Demand for petrochemicals scenario (million tons)

Regions/Countries	1985 Olef.	Arom.	Prim.	Plast.	Fibre	Rubb.	Other	End	Olef.	Arom.
Japan	8.1	4.0	12.1	5.0	1.1	1.0	4.5	11.6	9.5	5
Western Europe	22.2	8.0	30.2	12	2.2	1.5	11.0	26.7	26.0	9
North America	25.7	11.1	36.8	12.5	2.9	2.1	11.5	29	30.0	13.4
European CPEs	9.5	4.0	13.5	5.0	1.6	2.5	3.5	12.6	12.5	4.0
Other ind. countries	0.8	-	0.8	1.5	-	-	-	1.5	2	-
Total ind. countries	66.3	27.1	93.4	36	7.8	7.1	30.5	81.4	80.0	31.4
Tropical Africa, M.East, N.A., W. Asia	0.8	0.7	1.5	1.5	-	-	0.5	3.6	2.0	0.8
Rest of Asia	2.5	1.1	3.6	3.3	2.1	0.2	3.0	7.0	3.0	1.2
Asian CPEs	1.4	1.0	2.4	1.5	0.5	0.1	1.0	3.1	1.7	1.4
Latin America	3.0	1.1	4.1	2.7	0.6	0.6	1.0	4.9	3.3	1.2
Total devel. countries	7.7	3.9	11.6	9.0	3.2	0.9	5.5	18.6	10.0	4.6
World	74	31	105	45	11	8	36	100	90	36
Share of the DCs (%)	10.4	12.6	11.0	20.0	29.0	11.0	15.0	19.0	11.0	12.8

Table 11. Production of petrochemicals scenario (million tons)

Regions/Countries	1985 Olef.	Arom.	Prim.	Plast.	Fibre	Rubb.	Other	End	Olef.	Arom.
Japan	8.2	4.0	12.2	5.5	1.4	1.1	4.0	12.0	9.0	4.5
Western Europe	22.5	8.0	30.5	14.5	2.5	1.6	12.0	30.6	26.0	9.0
North America	25.5	11.1	36.6	13.8	3.0	2.1	13.0	32.0	30.0	12.5
European CPEs	9.5	4.0	13.5	4.5	1.5	2.5	4.0	12.5	12.5	5.0
Other ind. countries	0.8	-	0.8	0.5	-	-	-	0.6	2.0	-
Total ind. countries	66.5	27.1	93.6	39.0	8.4	7.3	33.0	87.7	79.5	31.0
Tropical Africa, M.East, N.A., W. Asia	0.7	0.7	1.4	0.3	-	-	0.3	-	2.0	1.0
Rest of Asia	2.4	1.1	3.5	2.2	1.6	0.1	0.7	5.2	3.0	1.2
Asian CPEs	1.4	1.0	2.4	1.0	0.4	0.1	0.8	2.3	1.7	1.3
Latin America	3.0	1.1	4.1	2.5	0.6	0.5	1.2	4.8	3.8	1.5
Total devel. countries	7.5	3.9	11.4	6.0	2.6	0.7	3.0	12.3	10.5	5.0
World	74	31	105	45	11	8	36	100	90	36.0
Share of the DCs (%)	10.1	10.8	10.9	13.3	23.6	8.8	8.3	12.3	16.7	13.9

1990						2000							
Prim.	Plast.	Fibre	Rubb.	Other	End	Olef.	Arom.	Prim.	Plast.	Fibre	Rubb.	Other	End
14.5	6	1.2	1.1	5.3	13.6	13	7	20	9	1.5	1.4	8	19.9
35	14	1.8	1.6	13.0	30.4	34	12	46	21	2.5	2.0	19	44.3
43.4	14	3.6	2.2	14.0	33.8	49	19	67	21	4.5	2.8	20	48.3
16.5	6	1.9	2.9	4.3	15.0	18	7	25	9	2.5	3.8	6	21.5
-	2	-	-	-	2.0	2	-	2	3	-	-	-	3
111.4	42	8.5	7.8	36.6	94.9	116	45	161	63	11	10.0	53	137
2.8	3.0	0.6	-	0.5		3.5	1.5	5.0	6.0	4.5	-	-	-
4.2	4.2	2.9	0.3	3.4	13.9	5.5	2.0	7.5	6.0	-	0.5	6.4	23.4
3.4	1.8	0.7	0.2	1.2	3.9	3.0	2.5	6.5	3.5	1.1	0.4	1.8	6.8
4.1	4.0	0.9	0.7	1.2	6.8	5.0	2.5	7.5	6.5	1.4	1.1	1.8	10.8
14.6	13.0	4.5	1.2	6.4	25.1	18.0	8.0	26.0	22.0	7.0	2.0	10.0	41.0
126	55	13	9	43	120	134	53	187	85	18	12	63	178
11.6	23.6	35.0	13.3	14.2	20.9	13.4	15.0	13.9	25.9	38.9	16.7	15.9	23.0

1990						2000							
Prim.	Plast.	Fibre	Rubb.	Other	End	Olef.	Arom.	Prim.	Plast.	Fibre	Rubb.	Other	End
13.5	6.5	1.6	1.1	4.9	14.1	12	6	18	11	2.0	1.4	7	21.4
35.0	15.5	2.4	1.7	14.0	33.6	34	11	45	23.5	3.7	2.0	20	49.2
42.5	16.0	3.6	2.3	15.5	37.4	48	16	64	24.5	4.2	2.8	22	53.5
17.5	5.2	1.9	3.0	5.0	15.1	18	7	25	8	2.6	3.8	7	21.4
2.0	0.8	-	-	-	0.8	2	1	3	1	-	-	-	1
110.5	46.0	9.5	8.1	39.4	103.0	114	41	155	68	12.5	10.0	56	146.5
3.0	1.3	-	-	-	-	4.0	2.5	6.5	2.5	3.3	-	-	-
4.2	2.8	2.1	0.15	1.1	7.45	6.0	3.0	9.0	5.5	-	0.5	2 ?	14
3.0	1.4	0.6	0.2	1.1	3.3	3.0	2.5	5.5	3.0	1.0	0.6	2.1	6.5
5.3	3.5	0.8	0.55	1.4	6.25	7.0	4.0	11.0	6.0	1.2	1.1	2.7	11
15.5	9.0	3.5	0.9	3.6	17.0	20	12	32	17	5.5	2	7	31.5
126	55	13	9	43	120	134	53	187	85	18	12	63	178
12.3	16.4	26.9	10.0	8.4	14.2	14.9	22.6	17.1	20.0	30.6	16.7	11.1	17.7

4.4.1 Industrialized countries

North America (GDP growth rate: 3.2 per cent/year)[37/]

The region has 4 per cent of the total world oil and 6 per cent of natural gas resources, it ranks third as producer of oil and first, with one third of the global resources as producer of gas in the world. Although in 1984 it imported 5.1 million barrels a day of oil, this is still less than 25 per cent of the total demand.

It is one of the world leaders in advanced petrochemical technology and represents between 35-40 per cent of the world total petrochemical production and demand. One to two per cent of domestic consumption is imported, while export accounts for 10.6 per cent of the production.

With the lifting of the price controls on home crude oil and gas production, the United States loses its significant cost advantage over its competitors in other industrialized countries. Strong competition in domestic markets from the neighbouring states of Mexico and Canada will influence the future development.

End products

Plastics. Demand for plastics rose 15 per cent in 1983 and again 6.5 per cent in 1984. In 1985 there will probably be a somewhat lower growth. Commodity plastics registered a healthy recovery, engineering plastics showed an even more vigorous growth. But considering that in 1983 only the 1979 level was reached, it seems appropriate to suppose a somewhat slower yearly growth until 1990 which can improve in the next decade. Commodity plastics, which now account for 70 per cent of the total will probably grow more slowly, while the higher impetus of the composites and engineering plastics will then have a share of 35 and 40 per cent respectively, i.e. roughly double the growth rate.

37/ The GDP growth rates in brackets in the title of each region are the UNITAD reference scenario's data for the period considered.

As far as the classic commodity plastics are concerned, a slow growth of around 2-3 per cent/year can be forecast.

The synthetic fibres and rubbers have less bright prospect. Competition from natural products and changing consumer attitude (fibres) as well as new products and technics (tyres) could prevent tnem from keeping the pace with GDP.

The remainder of the products contain the specialty products and other more sophisticated materials. The restructuring process underway can give a new impetus to them in the industrialized countries, so a somewhat higher growth rate can be assumed. For the whole group of the end products therefore an average growth rate is assumed.

Olefins consumption could increase to 33-35 million tons by 1990 if the end products are manufactured domestically. Since existing capacities will be soon inadequate to meet this demand, further expansion in the United States or Canada will have to be weighed against the import of olefins and/or end products from Mexico and even the Middle East.

Export will probably decline, but it can be assumed that in 1990 it will still be higher or equal to the imports, therefore, it is only in the last decade of this century that the region is expected to become a net importer of olefins and/or derivatives but then also only to a small extent. Imports of NGL from the North Sea and the Middle East are the most probable solutions for balancing regional production and imports. The highly organized petrochemical infrastructure, the elasticity and high technical and managerial level of this industry will be a great asset in the competition for this big market.

In the aromatic field the situation could be different. Demand is controlled by the non-petrochemical utilizations. Lead-free gasoline needs more aromatics and in this region motor fuel consumes a bigger part than anywhere else. While the demand for end products derived from aromatics could grow at a rate equal to that of the GDP, at the best, import of end products and of primary aromatics is likely to provide for the additional needs and so in this field the region will probably become a significant importer.

For the region as a whole, the GDP growth figure is 5.2 per cent. In the case of primary products, a factor of 1.15 can be applied, giving a yearly rate of 3.66 and 20 per cent over 5 years, with more emphasis on olefins and less on aromatics. The next ten years could be a little better, a factor of 1.23 and a yearly rate of 3.93 per cent could reflect the favourable raw material and technical level situation.

Western Europe (GDP growth rate: 2.3 per cent/year)

Although Western Europe's total oil resources are similar in size to those of the United States (around 4 per cent of the world global resources) and gas reserves are also significant (6 per cent of the world total) this region depends heavily on oil and gas imports for fuel and also for petrochemical purposes. The net oil import in 1984 amounted to over 8 million barrel/day or more than two-thirds of the consumption. Although starting only in the 1950s, activated by the refinery development and later on by the North Sea resources it became one of the leading petrochemical regions with over one third of the global capacity, production and demand. The oil crisis put heavy pressure on this industry and in spite of a high growth rate in the 1970s its share of the global figures declined. This tendency was most marked in the 1980s.

In view of the feedstock situation and the economics of production this tendency will remain valid.

Demand for commodity plastics will probably lose some markets but specialty engineering plastics and composites could develop considerably. There will be a difference in tonnage and money terms. Demand in quantity can show only a relatively low growth rate, while value could rise more rapidly, new products are starting with higher prices and smaller quantities. Synthetic fibres cannot maintain their positions. The clothing industry is turning towards natural fibres. The growing use in upholstery, carpets etc. and other industrial uses can probably just fill the gaps created by the lesser demand in the garments. So even in demand, little growth can be predicted. In production, strong competition from developing countries will prevail.

Synthetic rubber consumption could follow a rather subdued course and the production would have to adapt.

The trend towards more sophisticated products will not be restricted to the end products. Consumption and production of speciality intermediates, manufactured by high technology processes resulting from recent R and D activity could gradually replace the items transferred to other regions by the restructuring process.

Primary petrochemicals, having a somewhat better NGL but probably worse naphtha supply will face competition from producers with better access to cheap feedstocks. Either feedstocks and/or primary or even end products would have to be imported in substantial quantities. Therefore relatively slow growth can be predicted on the whole. In this overall picture, the repartition of the imports between the above possiblities cannot yet be predicted.

As a result of the above considerations a growth rate of 2.8 per cent/year for the period 1985 to 1990 and 2.5 per cent/year for 1990 to 2000 respectively was foreseen for the primary petrochemical production, while for the end products the corresponding figures are 1.9 per cent and 3.8 per cent respectively. The effect of the ongoing research is expected to give a new impetus to the development in the next decade by the entering of new specialty products in the commodity and therefore large volume sector.

On the demand side for the primary products 3 per cent/year and 2.75 per cent/year respectively, was foreseen, both figures being higher than those for the production, predicting importation of some primary petrochemicals. For the end products the respective figures are 2.6 per cent/year and 3.85 per cent/year, forecasting an importation of end products in the first period.

<u>European centrally planned economies</u> (GDP growth rate: 3.8 per cent/year)

The petrochemical industry is based mainly on the natural gas and oil from the USSR. Although most countries have their own reserves and production, none of them is able to cover the domestic demand. The USSR is

the world largest oil and gas producer with over 12 million barrels/day and 570 billion cubic metres respectively. Disposing of well developed refining capacities, and gas processing facilities, feedstock availability has not been hindering the development of the petrochemical industry in this region and it received high priority in the 1970s in all countries. End product consumption grew slower than production, and processes and equipment imported from Western Europe, Japan and the United States were paid for partly from the revenues of the exported surpluses. The 1980s have seen a slowdown of this development, but the drop in the production observed in the rest of the world did not occur in this region. In view of the feedstock situation, the growing market and the per capita consumption figures, the limiting factor of future development will be the amount accorded to the investment for creating new production facilities. Most products will be for domestic or regional consumption, but about 10 per cent of the commodity products could be exported. On the other hand many petrochemical products, intermediates as well as end products will have to be imported nearly balancing the sectoral trade.

More than 50 per cent of the total capacity and consumption lies with the USSR and the pattern for future development of the petrochemical industry of the region will be set by the Soviet industry, where the bulk of future capacities can be expected to come on stream. For both the end and primary products a balanced and steady growth can be expected, with more emphasis on the olefins and plastics, less on fibres and aromatics. Synthetic rubber has to retain its weight, natural rubber having a smaller impact in this region. Growth rate figures foreseen for the primary petrochemicals are 4.1 per cent/year and 3.6 per cent/year respectively while for the end products 3.5 per cent/year was foreseen for both periods.

Japan

With its petrochemical industry totally depending on imported feedstock, Japan was seriously affected by the oil crisis. In spite of the apparently fragmented sector with a large number of medium size producers the co-ordinated action led by MIT tends to revive this industry. High investment participation in joint ventures in the Near and Far East, transfer of basic and commodity production to areas with possible feedstock supply,

restructuring by mergers and co-operation at home and developing high technology products, keep this industry very active. Its share of the upturn in the period 1983 to 1985 was surprisingly high. In plastics e.g. demand grew even in commodity products by two-digit figures per year in several sectors, which of course was reflected, however in a dampened manner, in the basic and total petrochemical production. This shows that the emerging producers in the region, even if they have as joint venture partners Japanese companies, have to reckon with an innovative and expansion oriented competition from the producers.

In production 2.1 per cent and 2.9 per cent respectively for the primary products and 3.4 per cent and 4.3 per cent respectively was the yearly growth rate used, reflecting a growing import of primary products while for demand the rate was 3.2 per cent and 3.85 per cent respectively of primary petrochemicals utilized. The growth rates supposed are rather conservative.

4.4.2 Developing countries

Latin America (GDP growth rate: 2.9 per cent)

This region is one of the fastest growing petrochemical newcomers. Several countries have huge hydrocarbon resources and also big markets, the two conditions necessary for a healthy petrochemistry. Even countries like Brazil, having only a limited domestic hydrocarbon supply must solve their motorfuel problem and with it give petrochemistry a good starting position.

Mexico, Venezuela and Argentina are the main hydrocarbon-rich countries advanced already in the petrochemicals setting the framework of the future development of this industry. Brazil on the other hand in spite of its unfavourable raw material situation has already one of the fastest growing petrochemical industries in Latin America and will certainly be an equal partner in this field to the countries with abundant feedstock supply.

Mexico is the fourth largest oil producer and the fifth largest in reserves, has a big population and thus a large internal market. The vicinity of the United States opens an advantageous export market, too. Accordingly

the petrochemical industry has been receiving top priority treatment. Today it is a net importer of petrochemical products, but in the near future several million tons of product will appear in the international market, coming from Mexico. The petrochemical and chemical industry already well established, the scientific and technical background acquired and the incentives offered by the Government for areas outside Mexico City would allow a very rapid growth. A limiting factor will be the availability of funds for the investments needed. In this respect, Mexico is in a relatively better situation than most Latin American countries, so it can contribute more effectively to the petrochemical development of Latin America.

Venezuela has a well developed oil and gas industry. An important producer and large exporter in this field it had a slow and difficult start in petrochemicals. Now the existing plants are producing steadily and nothing impedes further development, first for the home market, then for the neighbouring countries.

Argentina has already a very important petrochemical industry and further extension is underway. Its significant oil reserves and crude production is a sound basis for future development for the big and expanding home market and also for other countries without such possibilities.

Brazil imports most of its crude oil, its own resources are insignificant. Although the National Alcohol Programme has already provided fermentation alcohol for the partial replacement of gasoline in large volume, most of the existing and comitted petrochemistry is based on petroleum products but large projects are foreseen on an alcohol basis. This country alone respresents around two-thirds of the existing Latin American petrochemical industry, and will in the future be one of the most important contributors to the development of this sector in the region.

Bolivia, Peru, Ecuador and perhaps some other countries could also play a significant role in the region's petrochemical future, in view of their feedstock situation and possible new discoveries.

Taking into account the favourable feedstock and market situation, the past trends and development goals, the region's development possibilities are high. The heavy debts and financial difficulties, however, could impede this development. With the next assumption, however, a good growth perspective can be forecast.

Assumption No. 5: Latin America will be able to overcome the present financial difficulties and provide the capital needed for the investments in the petrochemical industry.

On the production side, a growth rate in the primary petrochemicals of 5.2 per cent/year, corresponding to a factor of 1.8 for the period 1985 to 1990 and 4.6 per cent/year or a factor of 1.59 for 1980 to 1990 was supposed. End product production will grow at a somewhat faster pace, 5.55 per cent/year in the first and second period.

Middle-East Africa, Western Asia (GDP growth rate: 3.6 per cent)

In this region, the Gulf States and the North African countries represent the bulk of the existing and foreseeable petrochemical industry.

Gulf States. Saudi Arabia, possessing the largest resources in the world and ranking third as a producer of oil with much associated gas is already engaged in the creation of a big domestic petrochemical industry. After the methanol and ammonia plants, big olefin (ethylene) plants with end product manufacturing facilities will come shortly on stream. With the other Gulf States (Kuwait, Qatar) around 2.5 million tons of olefin capacity will be available in 1990. Further similar ventures will probably be scheduled only for the 1990s.

Iran and Iraq have ambitious plans for their petrochemical industry and have some production already but investment and production will start on a big scale only after the war has ended. Turkey in spite of its scarce resources has a more advanced petrochemical industry than their better placed neighbours and further investments are planned.

North Africa is also well placed from the point of view of petrochemical development. Egypt, Libya and Algeria have already olefin manufacturing and processing plants, Nigeria has large resources and had ambitious plans. Tropical Africa has less opportunity to join the countries with big petrochemical industries. Some countries have important reserves of hydrocarbons (Sudan, Gabon, Cameroon, etc.) and further discoveries can be expected but will have less impact on the petrochemical development of the region than e.g. the big oil exporting Gulf States, however, smaller units of local importance can be installed.

On the whole, the region has a very big potential for the development of the petrochemical industry, mainly from the feedstock side. The local market is rather limited in many countries and the creation of the necessary infrastructure for the industrialization still presents major difficulties. The drop in the oil revenues has reminded some of the would-be investors, that the financial possibilities, believed formerly to be unlimited, can become constraints to the development.

Nevertheless, the whole region will become gradually one of the major exporters in petrochemicals. Olefin production can rise in 1990 to over 3 million tons. This would give a factor of 3.85 and a growth rate of 14.6 per cent/year, but this outstanding achievement is already substantiated by the committed projects. For the next ten years a 9.6 per cent/year growth rate was supposed, the result of a high factor of 2.5.

In end products a similar growth can be expected in the next five years, since nearly all primary petrochemicals will be processed domestically. However, for the following ten years, exports of primary petrochemicals to both developing and industrialized countries was assumed, so the growth rate was set lower at 6.7 per cent/year for the end products.

East, South-East and South Asia (growth rate: 5 per cent)

This large region is composed of big consumers like India and big producers like Singapore and the Republic of Korea as well as countries having both large markets and feedstocks (like Indonesia) or neither of them. In the

last decade it became one of the world's important petrochemical producers and has the potential to become a sizable market force in both ways. The region represents already 30 per cent of the developing countries' primary and even more of the end petrochemical production and consumption.

The Indian subcontinent has a large population, but the GNP/capita figures ($US 140-380) of today implicate fewer market opportunities than those deducible from the population alone. Nevertheless, India has already an impressive petrochemical industry and the discoveries of the oil and gas fields led to further ambitious plans and projects. Its engineering capabilities and machinery industry together with its expanding chemical industry offer solid foundations for the further development of the petrochemical industry.

Pakistan with less oil but large gas reserves is also engaged in the petrochemistry and intends to follow the course initiated. Bangladesh having the lowest GDP/capita ($US 140), no oil and less gas is in a more difficult situation, but has projects in mind.

At the other end of the spectrum, Indonesia has large resources and a big population. The development of the petrochemical industry, already underway has good prospects. South Korea and Singapore have no sizeable crude or natural gas reserves, but within the framework of the overall expected industrialization of the next two decades, they installed big export oriented petrochemical complexes, based on refineries working with imported crude and exporting a good part of the products. The recent closures and underutilizations in the refinery sector create serious difficulties for these countries and for the future development of their petrochemical industry. Thailand and Malaysia have domestic hydrocarbon resources and some petrochemical industry, but good prospects for the future. The Philippines and Sri Lanka are less well placed because of the lack of hydrocarbon resources.

In th whole region the end product manufacturing, based on imported intermediates has a bigger role than anywhere else in the developing regions. The synthetic fibre industry has been developing rapidly.

Based on the industrial background, the hydrocarbon reserves and the actual trends, a growth rate of 3.8 per cent/year between 1985 and 1990 for the production of primary petrochemicals, and 7.4 per cent for the end products was foreseen. This will require imports from the oil-rich countries of olefins and aromatics in the countries of this region without adequate hydrocarbon resources. Even so, they will remain net importers of end products too, even if some countries will be net exporters (e.g. Indonesia).

Asian CPE countries

The People's Republic of China by itself practically sets the level of both consumption and production for the whole region. High crude oil and gas reserves, only partially explored, form a solid basis both for fuel (besides coal, of which the People's Republic of China has about 600 billion metric tons) and for a petrochemical industry of the size the country would need. The big projects of the late 1970s were cancelled in 1981 but could be restarted gradually. A steady growth from the already sizable basis of today was foreseen: 4.5 per cent/year for 1985 to 1990 and 6.2 per cent/year for 1990 to 2000 for primary petrochemicals and 7.4 per cent/year and 6.9 per cent/year respectively for end products.

4.4.3 Summary of the scenario

This scenario expects an overall growth rate of 3.77 per cent/year for the next five years for both primary petrochemicals and end products with olefins and plastics showing a higher growth rate of 4 per cent and 4.1 per cent respectively. For the last decade of this century, an overall growth of nearly 4 per cent was forecast, again with a similar distribution.

The share of developing countries would rise in both periods and for all products in production and demand.

Primary petrochemicals manufactured in the developing countries would represent instead of 10.9 per cent in 1985, 12.3 per cent in 1990 and 17.1 per cent in 2000. For the end products the actual 12.3 per cent would rise to 14.2 per cent in 1990 and to 17.7 per cent in 2000.

Demand would grow more slowly reflecting higher self sufficiency and growing exports: for primary petrochemicals from 11 per cent in 1985 to 11.6 per cent in 1990 and to 13.9 per cent in 2000 while for end products from 19 per cent in 1985 to 20.9 per cent in 1990 and 23 per cent in 2000. Details are shown in tables 10 and 11.

5. POSSIBILITIES FOR INCREASING THE ROLE AND SHARE OF THE DEVELOPING COUNTRIES

5.1 Classification of the developing countries

The possibilities and capabilities of the different developing countries for creating or expanding their own petrochemical industry vary widely between the two extreme situations, having everything and having nothing. The strategies and policies must necessarily be shaped according to these possibilities and capabilities. Every country has its individual endowments and needs an individual strategy and policy, which can only be designed and approved by itself. Nevertheless, it seems appropriate to group the developing countries in some more or less homogenous groups, for which a common general guideline can be proposed.

The development level reached by the different developing countries cannot be considered as a basis for the classification for two reasons:

(a) The development pattern of this sector does not follow a conventional path: it does not usually start with end-product manufacturing based on imported primary or intermediate ones. The general pattern is to start with the production of some primary chemicals and their processing to some of the end products.

(b) There is no definition of the petrochemical industry which is recognized world-wide and universally accepted and, therefore, there are no statistics on this industry as a sector or subsector.

The method adopted in this study for the classification uses as first variable, the size of the domestic market and as a second one, the availability of hydrocarbon resources.

Domestic market size. In view of the role played by petrochemical products in the whole national economy, it seems that for big countries the creation and development of a domestic petrochemical industry is mandatory

independently of the availability of hydrocarbon resources. The burden of the necessary imports on the foreign currency balance would otherwise be too heavy and would cause serious difficulties.

In the case of the domestic market, the main element used was the population, seconded by the GNP/capita figures.

Within the same domestic market sizes, the availability of domestic hydrocarbon resources is the dividing factor. Only two levels were considered: either the resources are adequate or larger than adequate for the development of a competitive domestic petrochemical industry in the country or not.

Based on these criteria, the following groups of countries were formed:

Group 1. Countries with a big domestic market (population of 100 million or more) and adequate hydrocarbon resources

Group 2. Countries with a big domestic market (population of 100 million or more) and no adequate hydrocarbon resources

Group 3. Countries with a medium-size domestic market (population between 25 and 100 million) and adequate hydrocarbon resources.

Group 4. Countries with a medium-size domestic market (population between 25 and 100 million) and no adequate hydrocarbon resources

Group 5. Countries with a small or no domestic market and large hydrocarbon resources

Group 6. Countries with a small domestic market and hydrocarbon resources smaller than necessary for a competitive petrochemical production.

Table 12 gives the necessary data for the grouping of the countries and table 13 the groups formed.

5.2 Strategies for the development of the petrochemical industry

The developing countries have shown great interest in petrochemicals. Not only have development strategies been worked out by most governments but they are being implemented successfully by many of them. The actual world

Table 12. Macroeconomic and petroleum resource indicators in developing countries

Countries	Population (millions)	GNP ($US bill.)	GNP/capita ($US/cap.)	Oil reserves (mill. MT)	Gas reserves (billion nm3)	Total reserves (mill. MT)	Total reserves (MT/cap)	Number of producing wells	Oil production (mill. MT/y)	Oil production/cap. (million MT/y/cap)	Number of refineries	Total capacity of refineries (mill. MT/y)
Latin America												
Argentina	28.4	58.9	2,070	352.4	697.5	875.5	30.791	8,189	26.5	932	11	38.5
Bahamas	0.2	0.8	3,850	-	-	-	-	-	-	-	1	19.9
Barbados	0.3	1.0	3,820	0.1	-	0.1	0.372	61	0.1	384	1	0.2
Bolivia	5.9	3.6	610	24.6	120.9	115.3	19.623	352	1.1	193	3	2.7
Brazil	126.8	274.6	2,170	307.3	80.4	367.6	2.899	3,386	24.8	196	13	74.1
Chile	11.5	25.2	2,190	114.4	66.8	164.6	14.327	266	2.2	188	2	8.0
Colombia	27.0	38.3	1,420	97.0	107.2	177.4	6.581	2,509	9.4	347	4	12.0
Costa Rica	2.3	2.7	1,150	-	-	-	-	-	-	-	1	0.9
Dominican Rep.	5.7	7.7	1,340	-	-	-	-	-	-	-	2	2.5
Ecuador	8.0	12.9	1,610	217.7	85.0	281.4	35.230	-	14.4	1,805	3	4.7
El Salvador	5.1	3.6	700	-	-	-	-	-	-	-	1	0.9
Guatemala	7.7	8.7	1,130	77.8	0.8	78.4	10.175	8	0.3	38	1	0.9
Honduras	4.0	2.6	660	-	-	-	-	-	-	-	1	0.8
Jamaica	2.2	2.8	1,240	-	-	-	-	-	-	-	1	2.0
Martinique	0.3	1.4	4,660	-	-	-	-	-	-	-	1	0.7
Mexico	73.1	200.5	2,740	7,557.3	2,180.6	9,192.8	125.718	-	155.7	2,129	9	72.0
Neth. Antilles	0.3	1.4	5,420	-	-	-	-	-	-	-	2	42.0
Nicaragua	2.9	2.5	860	-	-	-	-	-	-	-	1	0.9
Panama Ex Cz	1.9	4.1	2,110	-	-	-	-	-	-	-	1	5.7
Paraguay	3.1	4.9	1,570	-	-	-	-	-	-	-	1	0.4
Peru	17.4	22.0	1,260	104.2	31.2	127.6	7.311	4,083	11.4	654	6	10.0
Puerto Rico	3.3	12.1	3,730	-	-	-	-	-	-	-	2	6.9
Suriname	0.4	1.2	3,320	-	-	-	-	12	-	77	-	-
Trinidad & Tobago	1.1	7.7	6,920	84.0	298.8	308.1	276.032	3,145	9.6	8,594	2	18.2
Uruguay	2.9	10.0	3,400	-	-	-	-	-	-	-	1	2.6
Venezuela	16.7	68.9	4,140	4,018.9	1,568.0	5,194.9	311.818	13,512	97.8	5,873	7	69.5

Table 12. Macroeconomic and petroleum resource indicators in developing countries (cont'd)

Countries	Population (millions)	GNP ($US bill.)	GNP/capita ($US/cap.)	Oil reserves (mill. MT)	Gas reserves (billion nm3)	Total reserves (mill. MT)	Total reserves (MT/cap)	Number of producing wells	Oil production (mill. MT/y)	Oil production/cap. (million MT/y/cap)	Number of refineries	Total capacity of refineries (mill. MT/y)
Africa												
Algeria	19.9	46.8	2,350	1,399.5	3,089.7	3,716.8	186.670	1,090	34.5	1,733	4	26.4
Angola	8.0	...	...	279.9	46.7	314.9	39.408	291	11.7	1,470	1	1.8
Benin	3.7	1.2	340	15.6	-	15.6	4.214	6	0.4	106	-	-
Cameroon	9.3	8.2	880	85.5	117.5	173.7	18.743	166	7.1	766	1	2.4
Congo	1.7	2.3	1,370	74.6	60.0	119.6	69.875	246	6.7	3,912	1	1.2
Egypt	44.3	29.6	670	497.6	198.2	646.3	14.584	617	44.8	1,012	6	21.0
Ethiopia	32.9	4.6	140	-	-	-	-	-	-	-	1	0.8
Gabon	0.7	3.3	4,840	79.3	15.6	91.0	133.412	270	8.5	12,482	1	1.1
Ghana	12.2	4.2	340	0.6	0.1	0.7	0.056	3	-	3	1	1.6
Ivory Coast	8.9	8.2	910	16.8	85.0	80.5	9.010	19	1.2	140	2	5.1
Kenya	18.1	7.0	390	-	-	-	-	-	-	-	1	5.4
Liberia	2.0	1.0	490	-	-	-	-	-	-	-	1	0.9
Libya	3.2	27.1	8,430	3,281.1	600.4	3,731.3	1,160.242	905	61.9	19,234	3	18.7
Madagascar	9.2	3.0	320	-	-	-	-	-	-	-	1	0.9
Morocco	20.3	17.5	860	-	-	-	0.002	-	-	1	2	4.5
Mozambique	12.9	...	...	-	-	-	-	-	-	-	1	1.0
Nigeria	90.6	77.4	850	2,589.1	1,008.2	3,345.2	36.934	1,177	80.2	886	3	14.2
Senegal	6.0	3.0	490	-	-	-	-	-	-	-	1	1.7
Sierra Leone	3.2	1.2	390	-	-	-	-	-	-	-	1	0.6
Sudan	20.2	8.6	430	46.7	-	46.7	2.313	-	-	-	1	1.4
Tanzania	19.8	5.3	270	-	5.7	4.2	0.215	-	-	-	1	0.8
Togo	2.8	1.0	350	-	-	-	-	-	-	-	1	1.1
Tunisia	6.7	9.2	1,380	235.4	63.0	282.7	42.296	131	6.5	968	1	1.9
Zaire	30.7	5.6	180	17.1	0.8	17.7	0.578	16	1.5	50	1	1.0
Zambia	6.0	3.9	640	-	-	-	-	-	-	-	1	1.4

Table 12. Macroeconomic and petroleum resource indicators in developing countries (cont'd)

Countries	Population (millions)	GNP ($US bill.)	GNP/capita ($US/cap.)	Oil reserves (mill. MT)	Gas reserves (billion nm3)	Total reserves (mill. MT)	Total reserves (MT/cap)	Number of producing wells	Oil production (mill. MT/y)	Oil production/cap. (million MT/y/cap)	Number of refineries	Total capacity of refineries (mill. MT/y)
South/East Asia												
Bangladesh	92.9	12.8	140	-	198.2	148.7	1.601	-	-	-	1	1.8
Brunei	0.2	4.5	22,140	217.7	206.7	372.8	1,854.488	649	9.1	45,174	1	0.5
Burma	34.9	6.5	190	4.4	4.8	8.0	0.228	445	1.7	49	2	1.5
China	1,008.2	302.6	300	2,970.1	875.1	3,626.4	3.597	-	127.7	127	20	122.0
India	717.0	184.1	260	544.2	424.8	862.9	1.203	1,560	30.8	43	12	40.0
Indonesia	152.6	99.0	580	1,345.1	1,132.8	2,194.7	14.382	4,840	75.6	495	6	35.8
Korea, Rep.	39.3	75.1	1,910	-	-	-	-	-	-	-	6	44.0
Malaysia	14.5	27.1	1,870	466.5	1,416.0	1,528.5	105.211	368	26.2	1,805	4	11.6
Pakistan	87.1	33.0	380	12.8	446.3	347.5	3.988	38	1.0	12	3	7.3
Papua New Guinea	3.1	2.6	830	7.8	14.2	18.4	5.881	-	-	-	-	-
Philippines	50.7	41.5	820	2.5	0.3	2.8	0.055	10	0.7	13	3	16.2
Singapore	2.5	14.8	5,980	-	-	-	-	-	-	-	5	60.8
Sri Lanka	15.2	4.9	320	-	-	-	-	-	-	-	1	2.8
Thailand	48.5	38.4	790	24.3	167.1	149.6	3.082	84	1.1	22	3	9.7
West Asia												
Bahrain	0.4	3.8	9,870	26.4	205.6	180.6	475.362	257	2.3	6,123	1	14.2
Iran	41.2	...	...	7,541.8	13,554.0	17,707.2	429.474	530	122.9	2,981	4	30.1
Iraq	14.2	...	...	6,919.8	815.6	7,531.5	531.845	290	69.1	4,881	8	18.1
Jordan	3.1	4.2	1,340	-	-	-	-	-	-	-	1	5.7
Kuwait	1.6	30.6	19,610	13,995.0	920.4	14,685.3	9,401.601	530	52.5	33,607	5	37.9
Lebanon	2.6	...	...	-	-	-	-	-	-	-	1	1.0
Oman	1.1	6.9	6,370	544.2	208.9	700.9	649.618	555	22.9	21,248	1	2.8
Qatar	0.3	6.0	22,040	320.9	208.9	677.6	2,509.676	555	22.9	84,915	1	3.2
Saudi Arabia	10.0	158.6	15,820	26,279.5	3,491.0	28,897.8	2,882.569	555	257.9	25,729	4	47.7
Syrian Arab Rep.	9.5	15.9	1,680	225.5	36.2	252.7	26.714	802	9.1	966	2	13.0
Turkey	46.5	63.1	1,360	45.7	17.0	58.5	1.258	440	2.3	50	4	26.1
Yemen, Dem. Rep.	2.0	0.9	480	-	-	-	-	-	-	-	1	10.1

Table 13. Groups of developing countries

Group 1	Group 2	Group 3	Group 4	Group 5	Group 6
Indonesia	Banglades	Algeria	Burma	Angola	Bahamas
Mexico	Brazil	Argentina	Ethiopia	Bahrain	Barbados
Nigeria	China	Colombia	Rep. of Korea	Brunei	Benin
	India	Egypt	Thailand	Cameroon	Bolivia
	Pakistan	Iran	Turkey	Congo	Chile
		Iraq		Gabon	Costa Rica
		Malaysia		Kuwait	Dominica
		Nigeria		Oman	Ecuador
		Philippines		Qatar	El Salvador
		Syrian Arab Rep.		Saudi Arabia	Ghana
				Singapore	Guatemala
				Sudan	Honduras
				Trinidad & Tobago	Ivory Coast
				Venezuela	Jamaica
					Jordan
					Kenya
					Lebanon
					Liberia
					Madagascar
					Martinique
					Morocco
					Mozambique
					Netherland Antilles
					Nicaragua
					Panama
					Papua New Guinea
					Peru
					Puerto Rico
					Senegal
					Sierra Leone
					Sri Lanka
					Suriname
					Tanzania
					Togo
					Tunisia
					Uruguay
					Yemen
					Zaire
					Zambia
					Zimbabwe

situation, particularly that of the petrochemical industry, has nonetheless created some confusion. It seems therefore appropriate to respond to the recommendations of the Second Consultation and of the Advisory Panel Meetings and, based on the actual experience, to summarize the possible strategical approaches to the development of the petrochemical industry in the different developing countries, according to the grouping of section 5.1.

5.2.1 Countries with big domestic market and adequate hydrocarbon resources (Group 1)

These countries have already started the development of their own petrochemical industry and some of them have reached a high level of production. They are and will be able to implement their long-term plans for the realization of a more or less complete petrochemical structure with economically competitive size plants. Although their domestic market is potentially big enough to absorb all products, a substantial part of the output, as it is now, will be exported for two reasons:

(a) The domestic demand is rising continuously, whereas manufacturing capacity is being implemented in big steps. Instead of bridging the interim period by import, it is more advantageous for the country to be always ahead of the domestic demand and export the surplus. This strategy is used extensively in buy-back arrangements, where the plant equipment, know-how and license are paid back with the product surplus over and above the domestic needs.

(b) Government policies are generally aimed at exporting high value-added products instead of raw materials in order to earn more hard currency and utilize more manpower. Both aims can justify economically viable investments in the petrochemical industry beyond the domestic demand and even exclusively for export purposes.

The final goal for these countries is a more or less complete petrochemical production structure, from the primary to the end products with adequate downstream industries serving mainly the domestic market but providing for the needs of the other less endowed developing countries of the region and exporting a part of their products to the industrialized countries.

5.2.2 Countries with big domestic market and no adequate hydrocarbon resources (Group 2)

Several alternatives are open for this category of countries:

(a) Import of petrochemical products (intermediates and/or end products);
(b) Import of primary petrochemicals;
(c) Import of hydrocarbon feedstocks;
(d) Alternative domestic feedstock.

(a) The first is no real alternative. Importation of the ready-made end products would not only be financially difficult to bear, but would hinder the whole industrialisation process. Most of the petrochemical end products are for industrial or agricultural use.

(b) Import of primary or intermediate petrochemicals would in principle be feasible and in some cases could be a partial solution for some countries. However, in view of the interdependence between fuel, first of all motor fuel, and petro- chemical feedstock supply, this alternative would not solve the main problem, that of the fuel. The fuel issue is one of the most important strategic decisions for these countries, and the selection of the petrochemical feed- stock has to adapt itself to the solution of the fuel source. Therefore, in most cases one of the following alternatives could be adopted both for the supply of fuel and that of petrochemical feedstock.

(c) Import of hydrocarbon feedstock for fuel and petrochemicals. This is the route followed at least partly by some countries like India and the People's Republic of China, Brazil etc. It involves a much higher burden on the foreign currency balance than the import of petrochemical feedstocks only. Therefore, it can only be adopted by countries having enough exportable goods and/or having prospects of future discoveries of hydrocarbon resources. Even so, until these prospects materialize, at least for several petrochemical manufacturing processes, alternative feedstocks must usually be used. This has been the case e.g. with the ammonia production in the People's Republic of China and India.

(d) All above parameters will exert a strong pressure on the Governments of these countries to look for alternative domestic feedstocks, even when good prospects exist for future hydrocarbon discoveries. Petrochemicals or motor fuels coming from alternative feedstocks, be it biomass or other non-hydrocarbon fossil fuels, are not competitive today at the world market level with those coming from hydrocarbon sources and the situation will remain so for the next few years. However, this would be prohibitive only if instead of the domestic market export to the world market were aimed at. Local conditions such as inexpensive raw material and labour, together with the transportation costs for imported goods, could compensate at least partly for the higher investment and operating costs, especially if government incentives for foreign currency savings are considered. In many cases (e.g. Egypt, India) in the history of the last decades, plants based on local raw materials but with higher investment and operating costs proved to be very useful by introducing new manufacturing technology, creating industrial skills, training manpower, developing markets for the products and saving hard currency. Later on, when local hydrocarbon resources became available, retrofitting was not only possible but solved both the feedstock and rentability problems. In big countries, the existence of hydrocarbon sources is possible which perhaps may not solve the whole fuel problem but will cover the needs of the petrochemical industry.

For many countries of this group, the alternative feedstock solution poses great problems of capital allocation. With the scarcity of available financial means, the credit situation and the unemployment problem, the higher investment needs connected with the alternative feedstocks will be weighed against the advantages considered above.

These countries have the necessary governmentally supported organizations and skills to define their aims, strategic issues, and implementation policies - if this has not been done already. As experience shows, the solution lies in a combination of the above alternatives adapted to the individual prevailing conditions. In all cases, however, the development of the petrochemical industry and a fairly comprehensive industrial structure from primary to end products will certainly be one of the priorities to aim at. The pace of this development will depend largely on the GDP level. Low-income

countries will have to wait for the necessary capital accumulation (partly from local but mainly from outside resources) and concentrate at the beginning on the most important items, which will be in most cases ammonia, fertilizers and perhaps fibres.

5.2.3 Countries with medium-size domestic market and adequate hydrocarbon resources (Group 3)

The strategy of this group can be very similar to that of group 1. With only a few exceptions, these countries are usually already well advanced in the development of their petrochemical industry and have fixed their priorities and goals for the future. The difference to group 1 is only in size. The smaller domestic market does not justify a complete petrochemistry. Although most of the main primary, intermediate and end products can and will be produced, some important fields would be missing. Great care is necessary in the choice of the processes and products to be implemented and those omitted, depending above all on the local market conditions.

The second difference between group 1 and 3 is that, while in countries of group 1, usually several plants will be erected for the same manufacturing purpose, at times in the same time period, those of group 3 could have several plants for some basic primary and end products only like ammonia and fertilizer, and in most other cases one plant only to satisfy the domestic market. This underlines the importance of the process and product choices. Competition between domestic manufactures will be less pronounced than with group 1. Otherwise the considerations discussed in section 5.2.1 apply.

5.2.4 Countries with medium-size domestic market and no adequate hydrocarbon resources (Group 4)

There are two very different subgroups in this sector, according to the GDP/capita. The low-income countries (410 $US) that do not have any petrochemical industry worth mentioning (e.g. Ethiopia), and those in the low to middle income class (e.g. Turkey) that have a more or less sophisticated

petrochemistry, based either on some domestic hydrocarbon resources or on refineries processing imported crude. It can be foreseen, that although at a different pace and timing, all these countries will enter the industrialization pathway and thus develop the need for motor fuel and petrochemical end products.

The alternatives enumerated above in 5.2.2. apply here too but with a different aspect.

(a) Importing petrochemical end products is and will be the only way to cover the low-level needs of the countries with low income. The development of their petrochemical industry will probably have to lag behind domestic demand and only a step-by-step reduction of imports can be aimed at. Even the countries at the low to middle income level will generally only approach the consumption level with domestic production without reaching it and, in several manufacturing fields, will remain importers without domestic production. This underlines the importance of regional South-South co-operation. Some domestic markets may not be big enough to justify production in one country alone, but a specialization agreement can make countries of the same region complementary.

(b) The import of primary petrochemical products is and will be a serious alternative to be considered in South-South co-operation, either for a rather long but limited transition period, till the market has grown big enough and perhaps local resources can be found for the erection of a commercial-scale plant or as a definitive solution. Countries from group 5 could be natural partners for such co-operation.

(c) Import of hydrocarbon feedstocks for motor fuel and petrochemicals alike is a much more viable alternative for this group, than it is for group 2. The sheer size of the need, which makes the burden of foreign exchange unbearable for the very big countries, is not so heavy here and this could be in some cases the right solution for both problems, fuel and petrochemicals. It is clear, however, that for all purposes when hydrocarbon use is not justified, local resources should be utilized to the maximum extent possible.

(d) The same reasons have an opposite effect on the fourth solution, the use of alternative domestic feedstocks. For medium-sized countries, the situation will be different. They will have difficulties raising huge sums to invest in the use of alternative feedstocks and the pressure in this direction will also be substantially lower. So most countries of this group will probably not try to base their petrochemical industry completely or overwhelmingly on alternative local feedstock but certainly all of them will try to use their own resources wherever this solution is advantageous. This will however give only a modest role to the local supply.

5.2.5 Countries with small or no domestic market and large hydrocarbon resources (Group 5)

The development of the petrochemical industry for this group is the logical consequence of the situation. Huge quantities of associated gases have been flared and studies have shown that among the possible uses the most economic one is the local processing to petrochemical products. This solution brings to these countries not only higher value added in the products exported, but industrialization with all its consequences. Furthermore, the methane serves mainly for ammonia and methanol production, the high ethane and higher hydrocarbon content in these gases yields big amounts of C_2-C_4 fractions. These could be easily exported in liquid form and they will be to a growing extent in the next few years. It is obvious that local processing is and will be more advantageous for the producing countries. Many countries of this group have already started in this field and the entering in the world market of products from the successively commissioned new plants can be noticed. These countries tend also to refine part of the crude. This implies the processing of some refinery products (e.g. refining gases, aromatics from reforming) for petrochemical purposes.

For lack of corresponding local users, practically all of the products from these countries will appear on the world market with all the consequences already discussed.

The strategic question is not, should these countries follow this path and to what extent, but how far they should go in the processing, i.e. produce mainly primary petrochemicals and intermediates or go straight down to the end products.

The further down one goes on the processing ladder, the more the capital and raw material intensity of production decreases, while manpower demand increases. It is true that the value added also increases in parallel with the manpower demand. The strategy of this group will be to endeavour the development of a practically complete spectrum of primary products and only a few selected intermediate and end products, mainly from the bulk high volume range most of the output being export oriented.

The actual development strategy in these countries today is to concentrate mostly on integrated production, leaving no primary products or intermediates for export. It seems reasonable to suppose that the export of primary products will become more and more widespread for two destinations. First for the industrialized markets, as feedstock for the olefin-processing units, replacing the older plants having no feedstock background. Second, for the developing countries (groups 2, 4 and 6), which have domestic markets for the product and manpower, but no domestic feedstock.

This kind of trade can be based on long-term agreements, concluded mostly between or with the active participation of governmental bodies and on the creation of adequate corresponding logistic facilities.

5.2.6 Countries with a small domestic market and smaller than necessary hydrocarbon resources for a competitive petrochemical production (Group 6)

Small countries with no adequate feedstock availability will find it difficult to develop a petrochemical industry; indeed they will find that a more or less diversified, coherent petrochemistry is out of reach. Most of them would probably not wholly renounce the idea of having some part of this industry of their own, since the general industrialization process requires a corresponding petrochemistry. These countries will begin mostly with the

end-product manufacturing, selecting those goods which they themselves have used further in their downstream industry. Those with textile factories for example, will begin with one of the synthetic fibres importing perhaps first the chips and make only the spinning, and going upstream, import the intermediates for the chemical synthesis (e.g. DMTA or even o-xylene and ethylene-glycol for polyester production). In all cases, the backward integration and selective development will be the rule. The first step to be considered will automatically be in the downstream industries, e.g. plastic processing, to create a domestic market and accumulate the necessary capital and industrial skill for the next step up the ladder. Since no such country can reach a complete spectrum even in the end-product line, let alone the intermediate and primary fields, a broad field opens up for regional co-operation among countries from this group, based on specialization and exchange of products. Co-operation with countries of group 5 will be equally advantageous for both parties: further processing to end products and downstream activity in group 6 will create a bright and stable market for the primary products and intermediates coming from group 5.

6. POLICIES FOR THE IMPLEMENTATION OF THE STRATEGIES PROPOSED

The strategies for the development of the petrochemical industry in the various developing countries depend mainly on the feedstock and market conditions of the interested country. The policies to implement these strategies are necessarily more detailed, and become at the same time more diversified and depend on several groups of factors.

These interconnected and interdependent factors can be grouped in a four dimensional model, where the first dimension is the classification adopted in the previous section representing the factors feedstock and market. The second dimension is the development activity deployed, i.e. general government policy, individual project preparation and implementation with engineering, R & D, and investment realization as instruments and background for the development; operation of the existing plants and marketing. The third dimension takes into account the different fields of activity to be entered in each of the above phases, such as political, economic, technical, and commercial ones. A fourth dimension identifies wich solutions can be found by using the means of the country only, where South-South co-operation, be it regional or global should be sought or where North-South co-operation would be needed.

In this section, the second dimension was chosen as the main line to follow and the others will be considered in their relationship to this dimension.

6.1 General government policy

The experience shows that a prerequisite for the successful development of a petrochemical industry in the developing countries, among others, is a well founded, coherent, and consistent but elastic Government policy. This policy can take the shape of a system of incentives and regulations like it was the case with the United States (oil and gas price decontrol, research and development grants, etc.) or direct government involvement in national planning, organizational matters, and/or equity participation, like in the examples of Brazil, France, Japan, Mexico, etc.

This policy needs to take into account the resources of the country, viz. feedstock, infrastructure, finance, management, manpower, skill etc. and the market requirements and opportunities in order to identify the priorities, the goals to be achieved as well as the means to be used. The profile of the petrochemical industry to be developed has to be drawn and the implementation steps identified.

Two main aspects of this activity should be treated here: the information and the co-operation aspects.

6.1.1 Information

Sound economic planning and decision-making would be impossible without sufficient and up-to-date information. The policy has to be based on the knowledge of the world situation and trends related to the petrochemical industry, the available options as to processes, equipment, etc., R and D activities, the projects in implementation or under consideration, the whole market situation etc. not counting country specific data. Internationally available databases on the available technologies; capital goods; R and D activities; production, demand and trade figures and trends, if well established and constantly updated could provide the developing countries with the information necessary for the elaboration and updating of their policies.

6.1.2 Co-operation

The policies extend their perspectives beyond the borderlines of the countries involved. Resources as well as markets have to be considered in a global framework. Beyond the problems which can be solved domestically, most policy actions need partner involvement, regional, South-South and/or North-South co-operation. Petrochemical profiles of the different countries should match the pattern of the region and the global one. Complementarity or, even better, interrelated connections can greatly improve the efficiency of the whole development.

UNIDO has a substantial role to play in both fields. Among the issues proposed for the consideration of the Third Consultation the questions of information and co-operation and the tasks to be attributed to UNIDO are in the foreground.[38/]

6.2 Project preparation and implementation

Decisions on new investments have a special weight in our days. In the 1960s, wrong decisions were easily put right simply by the rapid development of the petrochemical industry, but now the losses caused by missed opportunities present less risk than unprepared and inappropriate investments. Therefore great care should be taken in the project preparation phase. Opportunity, pre-feasibility and feasibility studies should explore the situation and identify the economically justified and optimized project opportunities, determine the financial, feedstock, market conditions, make propositions for the most suitable products, processes, capital goods and other items subject to decision. A farsighted view is necessary to include all the operational problems (training, maintenance, spare parts, utilities etc.) and place particular emphasis on the marketing problems. Special attention should be paid to the co-operation necessities and possibilities.

Joint ventures and other financial arrangements are often necessary to provide not only the necessary capital but to pave the way for a smooth flow of the produced goods to the markets chosen, and in many instances to procure the process know-how and product trade-mark. This co-operation need not only be North-South but several developing countries also have opportunities to offer in all the above fields.

Engineering and investment implementation is a field for specially trained organizations. High and diversified skills, experience and good knowledge on the most up-to-date achievement, and of the relevant market are prerequisites. For the big investor in developing countries such

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38/ Aide-Mémoire and Issue Papers of the Third Consultation on the Petrochemical Industry.

organizations either exist already or will be gradually created, but for the smaller countries, regional co-operation or joining one of the bigger developing countries could be the solution.

6.3 Operation

Appropriate preparatory work and continuous monitoring of the high-technology petrochemical plants must be provided. Spare part supply, skilled preventive maintenance work, good management, uninterrupted training at all levels and special care on utility services are the most important items among the factors influencing the onstream factor and economic efficiency achieved. Co-operation in exchange of experience, maintenance, spare part inventory keeping, training etc. are opportunities not to be missed for the developing countries.

6.4 Research and development

A developing petrochemical industry cannot survive without a corresponding research activity. The creation and development of the necessary and opportune research facilities and organizations is perhaps the most challenging and most delicate task for a developing country.

Industrial research, cannot flourish without the necessary environment. It needs a local scientific, educational and industrial background. Close co-operation with universities and academic research organizations is as necessary as that with the every day industrial practice. Work has to be extended from bench scale to pilot plant. Contact with the international research and also the industrial community cannot be restricted to a well organized flow of information to the research workers, but close (personal) contacts with the leading world research organizations and industrial firms are vital elements.

Research in petrochemicals is expensive. Results will come but one must be aware of what kind of results to expect and when to expect them. R and D in this field is a rather long process and only gradual results can be expected.

A new research organizations' first results will be scientific and industrial knowledge enabling the organization to make well founded recommendations for the development policy to follow, for the right choice of products and processes to be purchased for implementation in the next projects and to assist in the evaluation of bids and in the implementation of the projects.

The second step would in most cases be product application. Service to the consumer in the processing of the products is a field where much help can come from these organizations.

In the third phase improvements in product quality and in process conditions can be sought. These improvements can enhance the economics of the production and strenghten the market position of the company.

It is only in the fourth stage and after tangible results in the above-mentioned three fields that the most demanding aims could be approached: the development of new products and processes.

A realistic policy in research is the only way to avoid frustration for both the management and the research workers.

6.4.1 Marketing

This is one of the most important and often one of the most neglected aspects of the petrochemical development work. The domestic market poses problems too, but all well founded feasibility studies should include an appropriate market research. The creation of the necessary domestic trade structure, if not without problems, presents usually less difficulties than the international one, where especially in the industrialized market, serious obstacles have to be overcome. To overcome these obstacles, developing countries have to adopt appropriate strategies and policies for a successful marketing activity.

Developing countries can tackle the marketing task in different ways, either seeking long-term co-operation (South-South or/and North-South) or taking the main burden of commercial activity themselves. Different countries and different products will evidently need different approaches and solutions.

6.4.2 North-South co-operation

For the inexperienced country, lacking the necessary world-wide sales network, the most obvious and effective way is to seek the co-operation of one or more big multinational companies. There are different forms of co-operation possible:

(a) Joint ventures

An equity participation in the manufacturing plant with clearly established responsibilities in the management and marketing can effectively solve most of the overseas marketing problems and help overcome the legal barriers (tariffs, etc.) too. This is the option used in many developing countries (Saudi Arabia, Iran, Qatar, Portugal, Iraq, Singapore, etc.). However on the long-term, in order to become knowledgeable and directly involved in the complex marketing activity, developing countries should negotiate special staffing arrangements. This will allow them to have a saying in the commercial aspects of the business later on but will not provide the world-wide sales network necessary for successful selling activity. This approach is most suited for the primary petrochemical products and in some cases, mainly if the joint venture party is the process owner, for end products too.

This strategy has already been adopted by Shell Oil and different other partners with SABIC with the planned imports of methanol, ethylene dichloride and styrene into the United States from Saudi Arabia. These volumes essentially pre-empt investment in the same products in the United States and other industrialized countries.

Another possibility is to negotiate selected plant closures with big producers in the industrialized countries. This is a difficult strategy to implement, but it has the very real advantage of providing high plant loadings at an early stage from the developing countries. It is the strategy adopted by the Japanese in moving over to imported methanol supply. However, it must be recalled that MITI's unique influence in Japan provides an umbrella under which companies in the same industry can co-operate with some degree of confidence and official support.

This is a worthwhile option to follow but it requires painstaking research into individual company positions before an approach is made with a firm proposition. The time frame should be from two to three years before the developing countries' plant is due to come on stream, to allow time for consideration, negotiations (especially with the trade unions) and structural changes in logistics (i.e. building extra storage tanks).

This strategy will yield the best results in large volume markets where companies are concerned about their own long-term position, for example in ethylene, ethylene glycol, EDC/VCM, methanol and ammonia.

In this case, the product of the user's plant would be mostly captively used by the industrialized countries partner in his own plants.

(b) <u>License agreement</u>

End products, plastics, fibres, etc. are in a way process-specific. The important characteristics of the product for the user depend to a certain extent on the process used. This fact is further enhanced by the wide publicity campaign usually deployed by the big manufacturers. For all these reasons, when developing countries buy a license from a process owner for the manufacturing plant (either directly or through a contractor), they often conclude an agreement allowing them to use the brand name of the process owner's product and/or a firm commitment of the licensor to take over and market a given part of the developing countries' products through his own

commercial services. Consumer and extension services are key elements in market penetration. The advantages and disadvantages of this approach are the same as for (a).

(c) Counter-purchase arrangements

A method of non-conventional entry into the chemical market which attained considerable success during the past decade or so is the counter-trade or counter-purchase agreements. A good number of these agreements became effective between east and west European countries and companies.[39/] Under such arrangements equipment, know-how, construction, technology, etc. are purchased against payments to be made either in products from the plants established or from other products during a certain period of time. One of the most popular forms of this arrangement is the "buy-back" agreements. The main characteristics of the buy-back agreements are:

- The value of individual transaction is higher than any form of counter-trade.
- The period of product take-back is relatively long, usually five to twenty years.
- The value of product take-back during the contract period usually equals the value of the plant, technology and/or equipment, minus initial down-payment, plus an amount to cover interest expenses during the period of take-back.

The advantages of such arrangements for the developing countries is that international payments will be balanced and that reserves of foreign exchange are preserved. In addition, they permit access to markets which may not be available through conventional methods.

39/ The development of chemical and petrochemical industries in the European CMEA countries, UNIDO/IS.486.

The disadvantages are that the market remains unknown and unpenetrated for the developing countries and, in many cases, the contractor who signs the deal is not really one of the established sellers of the product. This means he is not interested in buying more than the quantity fixed in the contract and must eventually use the services of a trader or distributor. In some cases, even low-selling prices and dumping charges may occur. A good example (although not in the industrialized/developing country relation) is the USSR-Occidental deal in ammonia delivery from the USSR against equipment and superphosphoric acid.

6.4.3 South-South co-operation

Co-operation among developing countries in the trade is naturally only one aspect or feature of the general petrochemical co-operation investment planning and production. In the commercial field this co-operation can appear in two main fields.

- Regional pool among developing countries of the same region to form one undivided market for the different petrochemical products coming from one single plant at the beginning, situated in one of the countries involved, and allowing the realization of plants with competitive capacity size. With the development of the consumption, other similar plants could successively be implemented in the other countries too. This regional co-operation has been followed e.g., in Latin America. The tariff difficulties experienced need serious consideration and propositions in this respect would provide great help to developing countries.

- Emerging producers of petrochemicals from developing countries will appear on the world market from all the main regions: Latin America, Near East and South-East Asia. Trying to compete on all markets would certainly overload the commercial capacities of the developing countries and at the same time would put all of them in a most disadvantageous condition on each market. Regional distribution of the markets will still secure healthy competition without undue burdens in transport, storage costs etc. and price disadvantages.

Direct sales

This is one alternative to the North-South co-operation to enter the developed market, but it can be at the same time complementary to the South-South co-operation above. Indeed, these direct sales can be developed as a joint activity of several developing countries, e.g. through a jointly owned and managed trading organization.

Alone or jointly, this option is the most difficult but the most attractive for the developing countries. It can give them the most realistic and continuing assess- ment and understanding of the industrialized markets and trends. The difficulties are great, however. A large trading organization with the necessary know-how and logistic support is needed, meaning high and sophisticated investment both in terms of goods and skilled staff. A storage and warehousing system must be implemented directly at the market place and all deliveries, even big ones, must come ex stock, otherwise shipping delays and other unavoidable difficulties will undermine the credibility of the developing countries and the conquest of the market will become even more difficult.

Characteristics of the producing developing countries, of the given market, and last but not least of the product will determine the best method to enter and conquer a market.

7. CONCLUSIONS AND RECOMMENDATIONS

The petrochemical industry is recovering from the effects of the world recession and oil crisis. It is difficult to estimate what part of the rapid growth in demand during the 1983-1985 period is to be attributed to stock replenishment, but it can be assumed that the world overall economic recovery induced a healthy growth in this sector, well above the industrial average. If the global economic situation remains favourable, the prospects for the petrochemical industry will be bright and this study supposed that during the period considered (up to 2000) the saturation or inflection point in the development of the petrochemical industry will not be reached yet.

The developing countries increased their share in both production and demand

Table 14. Share of the developing countries in production and conumption (per cent)

	1979	1984
Production		
Ethylene	7.1	11.2
Propylene	6.0	8.8
Butadiene	8.6	10.0
Benzene	6.9	10.25
Thermoplastics	9.0	13.2
Consumption (total)	16.4	19.7

The exports from developing countries are still small but major growth is expected. Their imports have shown a constant growth during the whole period from 1975 to 1984 in the framework of a declining overall import.

Hydrocarbons will remain the main feedstock for the petrochemical industry. There will be a gradual and slow shift from naphtha to lighter (LPG, ethane, NGL) and heavier (fuel oil etc.) feedstocks in olefin production. Alternative feedstocks will have local applications in the hydrocarbon-poor countries.

No major breakthrough but constant and important improvements are expected in the process field. New products should emerge mainly in the specialty fields, and they could have a serious impact on the whole petrochemical industry.

The ongoing restructuring process will continue. The hydrocarbon-rich developing and industrialized countries will have a major role mainly in the commodity field, while the industrialized countries will increase production of the high technology specialty items.

A scenario was elaborated forecasting the future development of the petrochemical industry. This scenario expects an overall growth rate of 3.77 per cent/year for the next five years for both primary petrochemicals and end-products with olefins and plastics showing higher growth rates, 4 per cent and 4.1 per cent respectively . For the last decade of this century, nearly 4 per cent overall growth was forecast, again with similar distribution.

The share of developing countries would rise in both periods and for all products in production and demand.

Primary petrochemicals manufactured in the developing countries would represent instead of 10.9 per cent in 1985, 12.3 per cent in 1990 and 17.1 per cent in 2000. For the end products the actual 12.3 per cent would rise to 14.2 per cent in 1990 and to 17.7 per cent in 2000.

Demand would grow more slowly reflecting higher self-sufficiency and growing export. For primary petrochemicals this will rise from 11 per cent in 1985 to 11.5 per cent in 1990 and to 13.9 per cent in 2000 and for end products from 19 per cent to 20.9 per cent in 1990 and 23 per cent in 2000.

The strategies and policies of the developing countries vary with the market size and feedstock supply. The developing countries can be classified in six different groups and corresponding strategies were presented for these groups.

The policies for the implementation of the strategies proposed lay great stress on the necessary information for decision-making and co-operation at regional level and in South-South and North-South relations. UNIDO could play an important role in promoting both information gathering and supply as well as co-operation.

In view of the importance of comprehensive up-to-date and reliable information to support the development of the industry, it would seem advisable:

(a) To initiate, by co-operation between international and regional bodies, the revision and updating of a statistical system in the field of the petrochemical industry in order to establish a coherent and consistent framework for the trade, production and demand statistics.

(b) To establish an efficient mechanism for the development and maintenance of a reliable and up-to-date database for the petrochemical industry.

(c) To continue the UNIDO work on the promotion of all forms of co-operation at the international level in the petrochemical industry.

Annex 1

Table A.1. Production of ethylene (thousand tons)

Region	1975 a/	1979 a/	1980 c/	1981 c/	1982 b/	1983 b/	1984 Forecast a/	1984 Actual b/
Japan	3,400	4,800	4,175	3,655	3,590	3,684	5,200	4,385
West. Europe	7,900	12,500	9,644	9,550	10,365	12,035	14,000	12,640
North America	9,700	14,300	14,200	14,433	12,212	14,196	18,500	15,665
URSS & E.Europe	2,000	3,000	1,200d/	1,400d/	4,128	4,310	5,000	4,650
Other industr.	250	500	2,723e/	1,668e/	520	520	750	520
Total ICs	23,250	34,950	31,942	30,706	30,813	34,745	43,450	37,860
Africa	-	-	-	-	-	-	-	-
Middle East, North Africa	-	100	30	55	100	100	400	100
Middle East, West AFrica	-	50	50	50	140	140	650	140
Asia	250	900	468	474	965	1,156	1,200	1,380
China	300	430	490	505	565	650	700	700
Latin America	600	1,200	1,080	1,100	1,555	1,828	2,500	2,020
Total DCs	1,150	2,680	2,118	2,184	3,325	3,874	6,550	4,340
World Total	24,400	37,630	34,060	32,890	34,138	38,619	49,600	42,200

a/ = Second World-wide Study
b/ = Market Trends and Prospects ECE Chemical Market Data Sheet, Chem/R.97/Add.1, 4 July 1985
c/ = Yearbook of Industrial Statistics 1983, United Nations (incomplete country coverage)
d/ = Without the USSR
e/ = With the USSR

Table A.2. Production of propylene (thousand tons)

Region	1975 a/	1979 a/	1982 b/	1983 b/	1984 Forecast a/	1984 Actual b/
Japan	2,300	3,100	2,565	2,659	3,100	2,970
West. Europe	4,100	6,500	6,003	6,460	7,200	7,000
North America	4,400	7,200	6,269	7,017	10,000	7,700
URSS & E.Europe	1,200	1,500	2,048	2,135	2,250	2,285
Other industr.	120	230	192	209	350	211
Total ICs	12,120	18,500	17,077	18,480	22,950	20,166
Africa	-	-	-	-	30	-
Middle East, North Africa	-	-	-	-	50	-
Middle East, West AFrica	-	30	30	30	80	30
Asia	200	450	529	636	900	689
China	70	210	314	390	350	4252
Latin America	200	500	686	720	1,000	800
Total DCs	470	1 190	1,559	1,776	2,410	1,944
World Total	12,590	19,720	18,636	20,256	25,310	22,110

a/ = Second World-wide Study
b/ = Market Trends and Prospects ECE Chemical Market Data Sheet, Chem/R.97/Add.1, 4 July 1985

Table A.3. Production of butadiene (thousand tons)

Region	1975 a/	1979 a/	1982 b/	1983 b/	1984 Forecast a/	1984 Actual b/
Japan	530	670	521	555	650	620
West. Europe	1,080	1,710	1,569	1,722	1,900	1,770
North America	1,250	1,750	987	1,179	1,900	1,270
URSS & E.Europe	300	400	1,192	1,260	800	1,310
Other industr.	75	110	52	55	110	65
Total ICs	3,235	4,640	4,291	4,771	5,369	5,035
Africa	-	-	-	-	-	-
Middle East, North Africa	-	-	-	-	60	20
Middle East, West AFrica	10	20	23	30	30	30
Asia	80	110	110	125	240	130
China	40	80	121	125	170	150
Latin America	80	210	175	189	400	225
Total DCs	210	420	419	469	900	555
World Total	3,445	5,060	4,710	5,240	6,260	5,590

a/ = Second World-wide Study
b/ = Market Trends and Prospects ECE Chemical Market Data Sheet, Chem/R.97/Add.1, 4 July 1985
c/ = Yearbook (incomplete data)

Table A.4. Production of benzene (thousand tons)

Region	1975 a/	1979 a/	1981 c/	1982 b/	1983 b/	1984 Forecast a/	1984 Actual b/
Japan	1,600	2,000	1,900	1,815	1,900	620	2,300
West. Europe	3,130	4,860	4,620	4,590	4,647	1,770	6,000
North America	3,670	6,400	5,055	3,976	4,720	1,270	7,400
URSS & E.Europe	2,150	2,600	2,678	2,814	2,915	1,310	4,000
Other industr.	80	140	120	100	106	65	230
Total ICs	10,680	16,000	14,365	13,295	14,288	5,035	20,430
Africa	-	-	-	-	-	20	
Middle East, North Africa	-	-	-	-	-	-	
Middle East, West AFrica	-	-	3	3	33	100	
Asia	180	360	360	357	424	650	
China	200	320	352	393	420	700	
Latin America	300	500	590	662	755	1,150	
Total DCs	680	1,180	1,305	1,415	1,632	2,620	
World Total	11,310	17,180	15,670	14,710	15,920	23,050	

a/ = Second World-wide Study
b/ = Market Trends and Prospects ECE Chemical Market Data Sheet, Chem/R.97/Add.1, 4 July 1985
c/ = Yearbook of Industrial Statistics 1983, United Nations (incomplete country coverage)

Table A.5. Production of thermoplastics (PE + PP + PVC + PS) (thousand tons)

Region	1975 a/	1979 a/	1982 b/	1983 b/	1984 Forecast a/
Japan	3,700	6,010	5,002	5,458	6,370
West. Europe	9,400	13,940	12,522	14,427	15,800
North America	7,550	13,240	12,190	13,547	17,400
URSS & E.Europe	2,030	3,540	3,940	4,233	5,770
Other industr.	300	690	610	663	990
Total ICs	22,980	37,420	34,264	38,298	46,330
Africa	-	-		-	-
Middle East, North Africa	-	90	50	17	30
Middle East, West AFrica	10	75	227	224	530
Asia	750	1,500	1,836	2,143	750
China	250	720	960	1,085	3,200
Latin America	740	1,360	2,136	2,244	1,200
Total DCs	1,450	3,745	5,199	5,713	2,800
World Total	24,430	41,165	39,463	43,193	48,510

a/ = Second World-wide Study
b/ = Market Trends and Prospects ECE Chemical Market Data Sheet, Chem/R.97/Add.1, 4 July 1985
c/ = Yearbook of Industrial Statistics 1983, United Nations (incomplete country coverage)

Table A.6. Production of PVC (thousand tons)

Region	1975 a/	1979 a/	1980 b/	1981 b/	1982 b/	1983 b/	1984 Forecast a/
Japan	1,130	1,590	1,429	1,129	1,218	1,420	1,790
West. Europe	3,100	4,320	3,619	3,215	3,450	4,000	4,700
North America	1,740	2,970	2,678	2,791	2,642	2,793	4,100
URSS & E.Europe	850	1,500	1,495	1,484	1,500	1,500	2,350
Other industr.	100	250	61	74	52	78	320
Total ICs	6,920	10,630	9,282	8,693	8,862	9,791	13,210
Africa	-	-	14	12	50	17	-
Middle East, North Africa	-	50	-	-	-	-	160
Middle East, West AFrica	-	40	30	41	42	44	160
Asia	200	740	817	842	916	1,034	1,380
China	220	350	484	487	553	638	700
Latin America	250	420	700	635	760	810	830
Total DCs	670	1,600	2,045	2,017	2,321	2,543	3,220
World Total	7,590	12,230	11,327	10,710	11,183	12,334	16,430

a/ = Second World-wide Study
b/ = Market Trends and Prospects ECE Chemical Market Data Sheet, Chem/R.97/Add.1, 4 July 1985

Table A.7. Production of LDP and LLDPE (thousand tons)

Region	1975 a/	1979 a/	1982 b/	1983 b/	1984 Forecast a/	1984 Actual b/
Japan	940	1,370	1,031	1,080	1,240	1,257
West. Europe	3,000	4,520	3,892	4,697	4,800	4,830
North America	2,380	3,920	3,867	4,117	5,000	4,225
URSS & E.Europe	600	1,130	1,287	1,369	1,660	1,410
Other industr.	120	210	254	265	320	265
Total ICs	7,040	11,150	10,331	11,528	13,020	11,997
Africa	-	-	-	-	-	-
Middle East, North Africa	-	40	45	45	200	-
Middle East, West AFrica	10	15	130	105	400	45
Asia	100	330	392	463	660	135
China	25	250	282	310	300	310
Latin America	320	450	669	719	1,030	770
Total DCs	455	1,085	1,518	1,672	2,590	1,773
World Total	7,495	12,235	11,849	13,200	15,610	13,770

a/ = Second World-wide Study
b/ = Market Trends and Prospects ECE Chemical Market Data Sheet, Chem/R.97/Add.1, 4 July 1985

Table A.8. Production of high density polyethylene (thousand tons)

Region	1975 a/	1979 a/	1982 b/	1983 b/	1984 Forecast a/	1984 Actual b/
Japan	350	800	643	686	840	842
West. Europe	1,350	1,770	1,592	1,884	2,000	1,995
North America	1,260	2,560	2,394	2,182	3,200	3,200
URSS & E.Europe	130	280	299	386	760	430
Other industr.	40	100	117	125	160	125
Total ICs	3,130	5,510	5,045	5,863	6,960	6,592
Africa	-	-	-	-	-	-
Middle East, North Africa	-	-	-	-	110	-
Middle East, West AFrica	-	-	-	-	110	-
Asia	50	100	188	191	370	253
China	5	20	52	63	30	65
Latin America	30	170	213	230	360	270
Total DCs	85	290	453	484	980	588
World Total	3,215	5,855	5,498	6,347	7,940	7,180

a/ = Second World-wide Study
b/ = Market Trends and Prospects ECE Chemical Market Data Sheet, Chem/R.97/Add.1, 4 July 1985

Table A.9. Production of polystyrene (thousand tons)

Region	1975 a/	1979 a/	1981 b/	1982 b/	1983 b/	1984 Forecast a/
Japan	690	1,230	1,183	1,180	1,180	1,360
West. Europe	1,300	1,800	1,735	1,706	1,762	2,200
North America	1,270	1,970	1,771	1,580	1,701	2,600
URSS & E.Europe	300	450	518	501	505	600
Other industr.	40	70	70	70	70	90
Total ICs	3,600	5,490	5,277	5,037	5,218	6,850
Africa	-	-	-	-	-	-
Middle East, North Africa	-	-	-	-	-	-
Middle East, West AFrica	-	20	-	-	-	30
Asia	50	150	80	80	80	280
China	-	10	20	21	22	20
Latin America	140	240	263	281	272	360
Total DCs	190	420	363	382	374	690
World Total	3,790	5,710	5,640	5,419	5,592	7,540

a/ = Second World-wide Study
b/ = Market Trends and Prospects ECE Chemical Market Data Sheet, Chem/R.97/Add.1, 4 July 1985

Table A.10. Production of synthetic fibres (thousand tons)

Region	1975 a/	1979 a/	1980 b/	1981 b/	1982 b/	1984 Forecast a/
Japan	980	1,800	1,400	1,430	1,350	1,350
West. Europe	1,800	2,270	2,270	2,400	2,250	2,240
North America	2,540	3,600	3,360	3,380	2,700	4,130
URSS & E.Europe	750	1,000	1,240	1,250	1,346	1,600
Other industr.	50	90	60	55	56	150
Total ICs	6,120	8,260	8,330	8,515	7,696	9,470
Africa	30	50	60	65	70	65
Middle East, North Africa	20	30	)	)	)	55
Middle East, West AFrica	60	90	) 951)	) 991)	) 1,196)	100
Asia	650	910	)	)	)	1,310
China	15	120	248	347	369	450
Latin America	400	600	567	564	489	840
Total DCs	1,175	1,800	1,826	1,967	2,124	2,820
World Total	7,295	10,060	10,156	10,482	9,820	12,290

a/ = Second World-wide Study
b/ = Market Trends and Prospects ECE Chemical Market Data Sheet, Chem/R.97/Add.1, 4 July 1985

Table A.11. Capacities (thousand tons)

Regions/Countries	Ethylene b/ 1984	Ethylene b/ Projects	Ethylene b/ Total	Propylene a/ 1984	Propylene a/ Projects	Propylene a/ Total	Butadiene b/ 1982	Butadiene b/ Projects
Japan	5,000	1,000		2,600	-		747	-
W. Europe	14,255	680		7,605	70		2,391	114
North America	18,620	135		10,335	-		3,157	-
URSS and E. Europe	6,000	1,270		2,768	460		415	240
Other industrialized countries	314	-		120	-		35	45
Total industrialized countries	44,554	2,985		23,428	530	23,958	6,745	399
Africa	-	-		-	-		-	50
Middle East North Africa	480	200		170	-		-	-
Middle East South Africa	444	1,756		5	-	-	-	-
Asia	1,670	1,467		994	450		267	192
China	1,650	300					76	-
Latin America	3,188	1,002		1,587	494		323	138
Total developing countries	7,432	3,413		2,756	944	3,700	666	380
World	51,986	6,398	58,384	26,184	1,474	27,658	7,411	779

a/ = Second World-wide Study
b/ = Market Trends and Prospects ECE Chemical Market Data Sheet, Chem/R.97/Add.1, 4 July 1985

Source: UNIDO database.

Table A.12. Relative world-wide importance of the petrochemical imports (in constant 1975 $US)

	1975						1980						1985					
	Million $US	Percentage of line 1	2	3	4	5	Million $US	Percentage of line 1	2	3	4	5	Million $US	Percentage of line 1	2	3	4	5
World total imports	880,156	-	-	-	-	-	1,144,254	-	-	-	-	-	1,043,691	-	-	-	-	-
World chemical imports	64,251	7.3	-	-	-	-	91,540	8	-	-	-	-	83,495	8.0	-	-	-	-
World petrochem imports	30,805	3.5	48	-	-	-	48,059	4.2	52.5	-	-	-	54,272	5.2	65	-	-	-
DC total imports	180,567	20.5	-	-	-	-	248,588	21.7	-	-	-	-	230,785	22.1	-	-	-	-
DC chemical imports	18,057	-	28.1		10.0	-	22,870	-	25.0	-	9.2	-	19,386	-	23.2	-	8.4	-
DC petrochem. imports	6,862	-	-	22.3	3.8	38	10,441	-	-	21.7	4.2	45.7	11,539	-	-	21.3	5.0	59.5
DME total imports	601,541	68.3	-	-	-	-	794,484	69.4	-	-	-	-	762,910	73	-	-	-	-
DME chemical imports	40,303	-	62.7	-	6.7	-	61,175	-	66.8	-	7.7	-	58,667	-	70.3	-	7.7	-
DME petrochem. imports	21,655	-	-	70.3	3.6	53.7	34,957	-	-	72.7	4.4	57.1	39,619	-	-	73.0	5.2	67.5
CPE total imports	67,065	7.6	-	-	-	-	79,399	6.9	-	-	-	-	49,183	4.7	-	-	-	-
CPE chemical imports	5,499	-	8.6	-	8.2	-	7,384	-	8.1	-	9.3	-	4,918	-	5.9	-	10	-
CPE petrochem.imports	2,146	-	-	7.0	3.2	39.0	3,176	-	-	6.6	4.0	43.0	2,705	-	-	5.0	5.5	5.5

Source: SITC.

Table A.13. Regional distribution of petrochemical imports (in constant 1975 $US)

	1975						1980						1985					
	Million $US	Percentage of line 1	2	3	4	5	Million $US	Percentage of line 1	2	3	4	5	Million $US	Percentage of line 1	2	3	4	5
Latin America																		
Region's total imports	54,249	30	-	-	-	-	67,674	27	-	-	-	-	39,472	17.1	-	-	-	-
Region's chemical imports	6,401	-	35.5	-	11.8	-	7,850	-	34	-	11.6	-	4,934	-	25.5	-	12.5	-
Regions's petrochemical imports	2,875	-	-	42	5.3	45	3,857	-	-	37	5.7	49	3,039	-	-	26.3	7.7	61.6
Tropical Africa																		
Region's total imports	18,512	10.3	-	-	-	-	24,559	9.9	-	-	-	-	17,401	7.5	-	-	-	-
Region's chemical imports	1,833	-	10.2	-	9.9	-	2,431	-	10.6	-	9.9	-	1,514	-	7.8	-	8.7	-
Region's petrochemical imports	407	-	-	5.9	2.2	22.2	687	-	-	6.6	2.8	28.2	574	-	-	5	3.3	38
North Africa																		
Region's total imports	18,499	10.2	-	-	-	-	19,874	8	-	-	-	-	23,680	10.3	-	-	-	-
Region's chemical imports	1,498	-	8.3	-	8.1	-	1,590	-	7	-	8.0	-	1,539	-	8.0	-	6.5	-
Region's petrochemical imports	481	-	-	7	2.6	32.1	596	-	-	5.7	3.0	37.4	734	-	-	6.4	3.1	47.7
West Asia																		
Region's total imports	37,036	20.5	-	-	-	-	59.223	23.8	-	-	-	-	64,001	27.7	-	-	-	-
Region's chemical imports	2,667	-	14.8	-	7.2	-	3,909	-	17.1	-	6.6	-	4,032	-	20.8	-	6.3	-
Region's petrochemical imports	963	-	-	14.0	2.6	7.2	1.481	-	-	14.2	2.5	37.9	2,176	-	-	18.9	3.4	53.9

Table A.13. Regional distribution of petrochemical imports (in constant 1975 $US) (cont'd)

	1975						1980						1985					
	Million $US	Percentage of line 1	2	3	4	5	Million $US	Percentage of line 1	2	3	4	5	Million $US	Percentage of line 1	2	3	4	5
South Asia																		
Region's total imports	10,169	5.6	-	-	-	-	13,022	5.3	-	-	-	-	12,140	5.3	-	-	-	-
Region's chemical imports	1,585	-	8.8	-	15.6	-	1,654	-	7.3	-	12.7	-	1,178	-	6.1	-	9.7	-
Regions's petrochemical imports	335	-	-	48.8	3.3	21.1	534	-	-	5.1	4.1	32.3	680	-	-	5.9	5.6	9.7
East Asia																		
Region's total imports	29,980	16.6	-	-	-	-	49,105	19.6	-	-	-	-	54,907	23.8	-	-	-	-
Region's chemical imports	2,638	-	14.6	-	8.8	-	3,978	-	17.4	-	8.1	-	4,393	-	22.7	-	8.0	-
Region's petrochemical imports	1,379	-	-	20	4.6	52.3	2,406	-	-	23	4.9	60.5	3,075	-	-	26.6	5.6	70.0
South-East Asia																		
Region's total imports	12,131	6.7	-	-	-	-	15,138	6.1	-	-	-	-	19,185	4.0	-	-	-	-
Region's chemical imports	1,371	-	7.6	-	11.3	-	1,468	-	6.4	-	9.7	-	1,765	-	9.1	-	9.2	-
Region's petrochemical imports	461	-	-	6.7	3.8	33.6	802	-	-	7.7	5.3	54.6	1.132	-	-	9.8	5.9	64.1

Source: SITC.

Table A.14. Relative world-wide importance of the petrochemical exports (in constant 1975 $US)

	1975						1980						1985					
	Million $US	Percentage of line 1	2	3	4	5	Million $US	Percentage of line 1	2	3	4	5	Million $US	Percentage of line 1	2	3	4	5
World total exports	835,654	-	-	-	-	-	1,092,190	-	-	-	-	-	983,421	-	-	-	-	-
World chemical exports	58,496	7.0	-	-	-	-	86,283	7.9	-	-	-	-	78,674	8.0	-	-	-	-
World petrochem exports	28,412	3.4	48.6	-	-	-	44,780	4.1	52.0	-	-	-	50,154	5.1	63.7	-	-	-
DC total exports	212,801	25.6	-	-	-	-	239,675	21.9	-	-	-	-	186,372	19.0	-	-	-	-
DC chemical exports	3,405	-	5.8		1.6	-	5,752	-	6.7	-	2.4	-	4,100	-	5.2	-	2.2	-
DC petrochem. exports	638	-	-	2.2	0.3	18.7	1,438	-	-	3.2	0.6	25	2,050	-	-	4.1	1.1	50
DME total exports	573,922	68.7	-	-	-	-	787,872	72.1	-	-	-	-	757,605	77.0	-	-	-	-
DME chemical exports	52,227	-	89.3	-	9.1	-	76,424	-	88.6	-	9.7	-	71,215	-	90.5	-	9.4	-
DME petrochem. exports	27,548	-	-	97.0	4.8	52.7	42,545	-	-	95.0	5.4	55.7	46,214	-	-	92.1	6.1	64.9
CPE total exports	47,088	5.6	-	-	-	-	59,773	5.5	-	-	-	-	38,371	3.9	-	-	-	-
CPE chemical exports	3,014	-	5.2	-	6.4	-	4,363	-	5.1	-	7.3	-	2,878	-	3.7	-	7.5	-
CPE petrochem.exports	706	-	-	2.5	1.5	23.4	1,136	-	-	2.5	1.9	26.0	1,266	-	-	2.5	3.3	44

Source: SITC.

Table A.15. Regional distribution of petrochemical exports (in constant 1975 $US)

	1975						1980						1985					
	Million $US	Percentage of line 1	2	3	4	5	Million $US	Percentage of line 1	2	3	4	5	Million $US	Percentage of line 1	2	3	4	5
Latin America																		
Region's total exports	44,798	21	-	-	-	-	56,377	23.5	-	-	-	-	52,129	28.0	-	-	-	-
Region's chemical exports	1,613	-	47.4	-	3.6	-	2,368	-	41.2	-	4.2	-	1,981	-	48.3	-	3.8	-
Regions's petrochemical exports	358	-	-	56.1	0.8	22.2	677	-	-	47.1	1.2	28.6	1,147	-	-	56.0	2.2	58
Tropical Africa																		
Region's total exports	19,780	9.3	-	-	-	-	20,869	8.7	-	-	-	-	14,423	7.7	-	-	-	-
Region's chemical exports	178	-	5.2	-	0.9	-	250	-	4.3	-	1.2	-	260	-	6.3	-	1.8	-
Region's petrochemical exports	20	-	-	3.1	0.1	11.2	21	-	-	1.5	0.1	8.4	14	-	-	0.7	0.1	5.4
North Africa																		
Region's total exports	15,528	7.3	-	-	-	-	18,382	7.7	-	-	-	-	12,388	6.6	-	-	-	-
Region's chemical exports	202	-	5.9	-	1.3	-	404	-	7.0	-	2.2	-	359	-	8.8	-	2.9	-
Region's petrochemical exports	-	-	-	-	-	-	55	-	-	3.9	0.3	13.6	74	-	-	3.6	0.6	20.6
West Asia																		
Region's total exports	91,327	43.0	-	-	-	-	77,757	32.4	-	-	-	-	37,461	20.1	-	-	-	-
Region's chemical exports	731	-	21.5	-	0.8	-	933	-	16.2	-	1.2	-	225	-	5.5	-	0.6	-
Region's petrochemical exports	91	-	-	14.2	0.1	12.4	78	-	-	5.4	0.1	8.4	150	-	-	7.3	0.4	66.7

Source: SITC.

Table A.15. Regional distribution of petrochemical exports (in constant 1975 $US) (cont'd)

	1975						1980						1985					
	Million $US	Percentage of line 1	2	3	4	5	Million $US	Percentage of line 1	2	3	4	5	Million $US	Percentage of line 1	2	3	4	5
South Asia																		
Region's total exports	6,626	3.1	-	-	-	-	7,849	3.3	-	-	-	-	7,527	4.0	-	-	-	-
Region's chemical exports	146	-	4.3	-	2.2	-	228	-	4.0	-	3.0	-	83	-	2.0	-	1.1	-
Regions's petrochemical exports	27	-	-	4.2	0.4	18.5	47	-	-	3.3	0.6	20.6	23	-	-	1.1	0.3	28.0
East Asia																		
Region's total exports	19,921	9.4	-	-	-	-	38,371	16.0	-	-	-	-	42,972	23.1	-	-	-	-
Region's chemical exports	398	-	11.7	-	2.0	-	1,458	-	25.3	-	3.8	-	1,074	-	26.2	-	2.5	-
Region's petrochemical exports	139	-	-	21.9	0.7	34.9	460	-	-	32	1.2	31.6	688	-	-	33.7	1.6	64.1
South-East Asia																		
Region's total exports	14,822	7.0	-	-	-	-	20,071	8.4	-	-	-	-	19,472	10.4	-	-	-	-
Region's chemical exports	89	-	2.6	-	0.6	-	100	-	1.7	-	0.5	-	156	-	3.8	-	0.8	-
Region's petrochemical exports	30	-	-	4.7	0.2	33.7	60	-	-	4.2	0.3	60.0	39	-	-	1.9	0.2	25.0

Table A.16. Trade balance, world, 1975, 1980 and 1983 (in constant 1975 $US)

		1975	1980	1983
World				
Total	export	835,654	1,092,190	983,421
	import	880,156	1,144,254	1,043,691
	balance	-44,502	-52,064	-60,270
Chemical	export	58,496	86,283	78,674
	import	64,251	91,540	83,495
	balance	-5,755	-5,257	-5,821
Petrochemical	export	28,412	44,780	50,154
	import	30,805	48,059	54,272
	balance	-2,393	-3,279	-4,118
Developing countries				
Total	export	212,801	239,675	186,372
	import	180,567	248,588	230,785
	balance	+32,234	-8,913	-44,413
Chemical	export	3,405	5,752	4,100
	import	18,057	22,870	19,386
	balance	-14,652	-17,128	-15,286
Petrochemical	export	638	1,438	2,050
	import	6,862	10,441	11,539
	balance	-6,244	-9,003	-9,489
Developed market economies				
Total	export	573,922	787,872	757,605
	import	601,541	794,484	761,910
	balance	-27,619	-6,612	-4,305
Chemical	export	52,227	76,424	71,215
	import	40,303	61,175	58,667
	balance	+11,924	+15,249	+12,548
Petrochemical	export	27,548	42,545	46,214
	import	21,655	34,957	39,619
	balance	+5,893	+7,588	+6,595

Note: The negative world-wide trade balance figures are due to the differences between import (c.i.f.) and export (f.o.b.) prices. This fact affects regional values as well.

Table A.16. Trade balance, 1975, 1980 and 1983 (cont'd)

		1975	1980	1983
Centrally planned economies				
Total	export	47,088	59,773	38,371
	import	67,065	79,339	49,183
	balance	-19,977	-19,566	-10,812
Chemical	export	3,014	4,363	2,878
	import	5,499	7,379	4,918
	balance	-2,485	-3,016	-2,040
Petrochemical	export	706	1,136	1,266
	import	2,146	3,174	2,705
	balance	-1,440	-2,038	-1,439

Table A.17. Trade balance, developing countries, 1975, 1980 and 1983 (in constant 1975 $US)

		1975	1980	1983
Latin America				
Total	export	44,798	56,377	52,129
	import	54,249	67,674	39,472
	balance	-9,451	-11,297	+12,657
Chemical	export	1,613	2,368	1,981
	import	6,401	7,850	4,934
	balance	-4,788	-5,482	-2,956
Petrochemical	export	358	677	1,147
	import	2,875	3,857	3,039
	balance	-2,517	-3,180	-1,892
Tropical Africa				
Total	export	19,780	20,869	14,423
	import	18,512	24,551	17,401
	balance	+1,268	-3,682	-2,978
Chemical	export	1,178	250	260
	import	1,833	2,431	1,514
	balance	-1,705	-2,181	-1,254
Petrochemical	export	20	21	14
	import	407	687	574
	balance	-387	-666	-560
North Africa				
Total	export	15,528	18,382	12,388
	import	18,499	19,874	23,680
	balance	-2,971	-1,492	-11,292
Chemical	export	202	404	359
	import	1,498	1,590	1,539
	balance	-1,296	-1,186	-1,180
Petrochemical	export	-	55	74
	import	481	596	734
	balance	-481	-541	-660

Table A.17. Trade balance, developing countries, 1975, 1980 and 1983 (cont'd)

		1975	1980	1983
West Asia				
Total	export	91,327	77,757	37,461
	import	37,036	59,223	64,001
	balance	+54,291	+18,534	-26,540
Chemical	export	731	933	255
	import	2,667	3,909	4,032
	balance	-1,936	-2,976	-3,777
Petrochemical	export	91	78	150
	import	963	1,481	2,176
	balance	-872	-1,403	-2,016
South Asia				
Total	export	6,626	7,849	7,527
	import	10,161	13,022	12,140
	balance	-3,535	-5,173	-4,613
Chemical	export	146	228	83
	import	1,585	1,654	1,178
	balance	-1,439	-1,426	-1,095
Petrochemical	export	27	47	23
	import	335	534	680
	balance	-308	-487	-657
East Asia (Mfg)				
Total	export	19,921	38,371	42,972
	import	29,980	49,105	54,907
	balance	-10,059	-10,734	-11,935
Chemical	export	398	1,458	1,074
	import	2,638	3,978	4,393
	balance	-2,240	-2,520	-3,319
Petrochemical	export	139	460	688
	import	1,379	2,406	3,075
	balance	-1,240	-1,946	-2,387

Table A.17. Trade balance, developing countries, 1975, 1980 and 1983 (cont'd)

		1975	1980	1983
South-East Asia				
Total	export	14,822	20,071	19,472
	import	12,131	15,138	19,185
	balance	+2,691	+4,933	+314
Chemical	export	89	100	156
	import	1,371	1,468	1,765
	balance	-2,282	-1,368	-1,609
Petrochemical	export	30	60	39
	import	461	802	1,132
	balance	-431	-742	-1,093

Table A.18. Thermoplastic demand (thousand tons)

	1975			1979			1983		
	Demand	Production	Balance	Demand	Production	Balance	Demand	Production	Balance
Japan	2,940	3,700	+760	5,460	6,010	+550	4,690	5,458	+768
Western Europe	7,300	9,400	+2,100	12,430	13,940	+1,510	12,095	14,427	+2,332
North America	7,230	7,550	+320	11,010	13,240	+2,230	11,900	13,547	+1,647
USSR and Eastern Europe	2,350	2,030	-320	3,590	3,540	-50	4,700	4,233	-467
Other industrialized countries	600	300	-300	800	790	-10	1,450	663	-787
Total industrialized countries	21,320	22,980	+1,660	34,290	37,420	+3,130	34,835	38,328	+3,493
Africa and Middle East	640	10	-630	890	165	-725	1,505	241	-1,264
Asia	1,540	700	-840	3,650	2,220	-1,430	4,640	3,228	-1,412
Latin America	1,100	740	-360	2,170	1,360	-810	2,400	2,244	-156
Total developing countries	3,280	1,450	-1,830	6,720	3,745	-2,975	8,545	5,710	-2,832
World total	24,600	24,430	-170	41,030	41,165	+135	43,380	44,041	+661

Source: UNIDO database.

Annex 2

1.1 Background

1. In the framework of the system of consultations recommended by the Second General Conference[40/] of the United Nations Industrial Development Organization (UNIDO) and established by the General Assembly at its seventh special session in September 1975,[41/] the Industrial Development Board at its twelfth session[42/] authorized UNIDO to convene a consultation meeting on the petrochemical industry which was held in Mexico City, Mexico, from 12 to 16 March 1979.[43/]

2. The Consultation discussed the First World-wide Study on the Petrochemical Industry: 1975-2000[44/] introduced by the Secretariat and showing[45/] that

- The developing countries produced approximately 8 per cent of the world petrochemical output in 1975,

- The demand for petrochemicals in developed countries with market economies had stagnated since 1974, leaving excess capacity to supply petrochemicals,

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40/ Report of the Second General Conference of the United Nations Industrial Development Organization (ID/CONF.3/31), chapter IV, "The Lima Declaration and Plan of Action on Industrial Development and Co-operation", para. 66.

41/ Official Records of the General Assembly, Seventh Special Session, Supplement No. 1, para. 3.

42/ Official Records of the General Assembly, Thirty-fourth Session, Supplement No. 16.

43/ First Consultation Meeting on the Petrochemical Industry, Mexico City, 12-16 March 1979, Report (ID/WG.291/9(Rev.1)

44/ First World-wide Study on the Petrochemical Industry: 1975-2000. UNIDO/ICIS.83.

45/ First Consultation Meeting on the Petrochemical Industry, Mexico City, 12-16 March 1979, Report (ID/WG.291/9(Rev.1), page 14.

- A major shift in the cost structure of producing petrochemicals had taken place since 1975, raising the proportion of total costs attributable to feedstocks in the cost of ethylene from 44 per cent in 1972 to approximately 80 per cent with current naphtha spot prices (1979).

3. The possible increase of the developing countries' share in the production was also discussed. The scenarios presented in the study: to increase this share to 18-35 per cent of the world petrochemical output was found too high.

4. The Consultation recommended among others the establishment of a permanent working group on world supply[46/], the updating of the World-wide Study[47/] and the convening of a second consultation meeting. Co-operation involving Governments and industrial companies in both industrialized and developing countries was recommended as the main method to achieve the development of the petrochemical industry in the developing countries. The most important fields identified for co-operation were marketing and technology transfer.

5. By decision of the Industrial Development Board at its thirteenth session in 1979,[48/] the Second Consultation on the Petrochemical Industry was held in Istambul, Turkey from 22 to 26 June 1981,[49/] where the Second World-wide Study on the Petrochemical Industry[50/] and a joint study of The Industrial

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46/ Ibid. p. 6.

47/ Ibid. p. 9

48/ Official Records of the General Assembly, Thirty-fourth Session, Supplement No. 16.

49/ Second Consultation on the Petrochemical Industry, Istambul, Turkey, 22-26 June 1981, Report (ID/WG/Corr.1, ID/WG.336/7(Rev.1/Corr.1).

50/ Second World-wide Study on the Petrochemical Industry: Process of Restructuring (ID/WG.336/3).

Uses of Associated Gas[51/] among others were presented. The first one examined the world supply and demand for petrochemicals up to 1990 and considered trends in availability and cost of feedstocks and international trade in petrochemicals as well as prospects of global co-operation in the industry.

6. The Second Consultation meeting recommended to the Secretariat to examine the various forms of long-term arrangements for the development of the petrochemical industry in the developing countries and to develop a programme of co-operation among developing countries.[52/]

7. Following the recommendations of the Second Consultation, UNIDO jointly with OPEC and the OPEC Fund for International Development convened a Seminar on Co-operation Among Developing Countries in the Petrochemical Industry to define the framework of co-operation possibilities (Vienna, 3-9 March 1983).[53/] This seminar recommended[54/] the elaboration of a study on opportunities for the petrochemical industry in developing countries under the title "Global Outlook of the Petrochemical Industry and the Emerging Role of the Developing Countries", in order to give to the participants of the Third Consultation Meeting a summary of the situation in the petrochemical industry regarding capacities, production, consumption and trade; presenting the the results of cost analyses, forecasting scenarios and proposing corresponding strategies for the development of the petrochemical industry in the different developing countries.

51/ "The industrial Uses of Associated Gas" by the United Nations Industrial Development Organization in Co-operation with Gulf Organization for Industrial Consulting and Organization of Arab Petroleum-exporting Countries.

52/ Second Consultation on the Petrochemical Industry, Istambul, Turkey, 22-26 June 1981, Report (ID/WG/Corr.1, ID/WG.336/7(Rev.1/Corr.1)

53/ "On Co-operation Among Developing Countries in Petrochemical Industries," Report of the OPEC/UNIDO/OPEC Fund Seminar, Vienna, 7-9 March 1983.

54/ Ibid.

8. The above seminar also recommended that UNIDO forms an advisory panel of experts to implement the recommendations of the seminar. UNIDO convened threepanel meetings jointly with OPEC and OPEC-Fund.[55/] The meetings considered different co-operation issues, prepared terms of reference for co-operation arrangements and recommended further co-operation among developing countries.

55/ - The First Advisory Panel Meeting, Vienna, Austria, 3-4 October 1983
- The Second Advisory Panel Meeting, Vienna, 17-18 September 1984
- The Third Advisory Panel Meeting, Vienna, Austria, 3-5 March 1985.

Annex 3

Logistics and trade

1. Logistics

Transport, storage and handling of petrochemicals is not only a cost factor. Special facilities (ships, terminals, tank farms, special railway and road vehicles) are often needed and their non-availability can hinder or even prohibit the entering into a market.

1.1 Technical aspects

According to handling problems and methods, the petrochemical products have been classified as follows:

A. Oil-based feedstocks
B. Chemical gases
C. Basic chemical liquids
D. Liquid chemical intermediates
E. End products - solids.

A. Oil-based feedstocks (e.g. naphtha, gas oil, NGL/LPG, condensates)

The bulk of oil-based feedstocks for olefins and aromatics production are supplied "over-the-fence" by short pipelines from nearby refineries or gas liquids fractionation plants. Occasionally, somewhat longer pipelines might be used.

Apart from feedstocks transportation savings, it is the fact that the co-products or by-products from ethylene cracking (pyrolysis gasoline, raffinate (minus aromatics) or C_4 streams) are usually processed in the refinery, which makes an over-the-fence logistic system the prime favourite.

However, regular imports of large volumes of naphtha and condensates have been registered (10-15 million tons per year) and, in the future, shipping of LPG, chiefly from the Middle East, North Africa and the North Sea will develop.

The importing companies usually take delivery of 20,000 metric ton cargoes, either directly into their own storage or via the extensive public terminals in all industrial areas.

Condensates move in the same way, in 20-25,000 metric-ton oil tankers.

LPG, which is a feedstock only now gaining popularity for ethylene production is facing logistics problems because of the lack of either directly owned or public terminalling facilities. The build-up of imported LPG usage by the European chemical industry, to a level of say 7 million metric tons per year, will take time, because of the slow pace of import terminal building. LPG export availability and much of the specialised shipping are already in existence.

Japan and the USA are believed to be in a better position than Western Europe as regards LPG terminals, because of the higher levels of historical LPG fuel usage, the existence of specialist LPG companies and the long-standing use of LPG feedstocks for ethylene production.

B. Chemical gases (e.g. ethylene, propylene, butadiene, VCM and ammonia)

Access to specialised handling facilities is a basic requirement for any logistic involvement in the chemical gases business, whether in the form of ships, terminals or pipelines. As a result of these requirements, the chemical gases trade remain in the hands of relatively few companies.

There is a restricted number of publicly available storage locations with the appropriate facilities, so new entrants into this business will encounter logistic problems, unless selling directly to end users with storage.

Most product transfers within the industrialised areas, are currently made by coastal vessels, pipeline or truck. External trade is small.

It is not thought that there is currently any ethylene or propylene trade from or to the USA and Japan. However, ethylene is slowly becoming an article of international commerce, particularly for new chemical complexes, in isolated locations. Greece and Venezuela have been, or plan importing and Portugal (CNP) and Algeria (Sonatrach) have been exporting.

VCM

In Western Europe, nearly all VCM production is fully integrated with ethylene dichloride facilities. Over the last two decades, the VCM business in the USA increased the percentage of merchant sales, to about 2/3 of the total volume.

These very large volumes of merchant VCM moves between producers primarily by railcar and tranktruck, however, there are also a number of coastal terminals.

In Japan nearly all the VCM producers are also PVC producers. There are individual imbalances, which have led to an inter-producer merchant market. These movements are made mainly by rail and truck. There do not appear to be many terminals to handle VCM imports.

Ammonia

The international ammonia trade and therefore the logistics pattern, has been undergoing fundamental changes in recent years because the level of imports of natural gas-based ammonia has increased so dramatically. The quantity of merchant ammonia traded internationally is counted in million tons per year and is continuously expanding. Logistics facilities (ships, terminals, storage) will by now be available in Western Europe, Japan and the USA.

Ethylene/propylene/butadiene

There appear to be no ethylene or propylene imports or exports from or to Japan and the USA. However, the USA is a major importer of butadiene and facilities certainly exist along the coastline to take this product. Ethylene

and propylene net exports from Western Europe are negligible and so far there have been only minor net ethylene imports from Algeria, Italy and Spain, into existing terminals, with no known propylene imports.

The very extensive and complex inter-producer/consumer pipeline grid systems which exist in Europe and the Gulf gives little possibility for an overseas producer to supply ethylene into these grids without the co-operation of one of the participants with a sea pipeline linkage. Nearly all ethylene ships are refrigerated, whereas the pipelines are pressurised. The problem of unloading ethylene from ships and into pressurised storage, for connection into the pipelines, is a major one. Direct transfer from a ship into the grid is not possible.

C. Basic chemical liquids (e.g. benzene, xylenes, methanol)

The vast bulk of these basic chemical building blocks move by conventional means, i.e.

- short pipelines
- barges
- tanktrucks
- railcar
- ocean-going parcel tankers.

All these products can be shipped in mild steel (uncoated) tanks and stored under similar conditions. Considerable tankage in public terminals is available, making the movement of products by importers, exporters and traders an easy matter.

Marketers make use not only of their own facilities, but also of rented storage and barges. There will be few problems for a new producer from a developing country finding product storage and distribution facilities in Europe, the USA or Japan for these types of product.

D. Liquid chemical intermediates (e.g. styrene, ethylene glycol, acrylonitrile, ethylene dichloride)

Storage facilities for imports will be found readily available for styrene and ethylene dichloride. Fibre grade ethylene glycol storage will be harder to find, and the use of stainless steel tanks is the best insurance against off-specification product. However, dedicated coated storage would be suitable and is cheaper and more readily available. It is throught that acrylonitrile storage is not readily available for lease and is primarily in the hands of the producers.

E. End products - solids

The majority of end products at the next stage downstream from the basic chemicals tend to be solids, either polymers, fibre intermediates, rubbers, fertilizers or resin precursors.

The largest volume of movements of these products is still made in 25 kg and 50 kg plastic or multiwall paper bags (on pallets).

For larger end-user customers there has been a recent tendency towards using special "bulk" 20 foot steel box containers, with an opening top and a large polyethylene liner. Other methods now being used include large 1 metric ton woven polypropylene sacks, termed "mini-bulk", lifted by forklifts or cranes.

Container handling services and dry-product warehousing facilities are already in use in the developed areas, so that the less developed countries would have no problems in shipping-in polymers or other products, in bags or containers.

1.2 Cost aspects

Among the cost component making out the difference between factory- gate price and selling price on the relevant market place, the most transparent and less variable are the transport costs. The others, tariffs, marketing and commercial expenses are much more variable and difficult to assess.

Transport costs have not varied substantially since the elaboration of the Second World-Wide Study (ID/WG.336/3). The main conclusions remain true: transport costs are low (under 10 per cent of the selling price) for the intermediates, between 10 and 15 per cent for the end and most basic products, but between 20 and 30 per cent for the ammonia, and fertilizers. The difference in freight rates is much smaller than in the unit price and that is reflected in the above figures.

Although the shipping costs cannot be neglected, for most products, they would not impede by themselves the export of petrochemicals from the developing countries. Examples like the several million tons of ammonia shipped yearly show that these costs are considered as unavoidable and can be compensated by low feedstock costs and other factors.

Freight cost can be minimized by adequate shipping methods (use of bigger cargos, back-haul assured, etc.) but first of all by rational choice of the market. Regional distribution of the market between developing countries entering into the petrochemical export field would not only reduce transport costs but avoid over-competition and possible market disruption.

2. Trade

The second important cost factor group is connected with the market: commercial services, stockage, customer service, etc. This is not only a cost factor, often it will decide on the success or future of the whole commercialisation of the product and hence of the project itself. It is therefore most important for the developing countries to understand the market structure of the petrochemicals.

The output of the manufacturing plants reaches its destination through one of the following channels:

(i) Direct utilisation in another plant of the same company or group of companies, without intervention of any commercial activity; This is the captive use, which, in many cases, especially with basic products and some monomers can absorb the majority of the products on output.

Integrated production structures, incorporating several consecutive production steps are characteristics for petrochemicals in the industrialized countries.

Of the three main industrial areas, integration is at the highest level in Western Europe, between building block chemicals and downstream derivatives. This has been brought about mainly by the intense levels of competition. In the USA there is a high level of integration, but the sheer size of the market has enabled a much larger number of non-integrated downstream producers to stay in business. This situation will not change dramatically in the USA because of the existence of the anti-trust laws. By West European standards olefins integration levels in Japan must be considered low.

(ii) Concentrated merchant markets. The quantity not consumed within the manufacturers' own structure is traded mostly between a few larger companies on a long-term contractual basis. Traders and distributors are not involved; manufactuers and users are in direct contact. The overriding attitude is governed by the fact that both partners need each other on a long term basis. The market prices and conditions are consequently less prone to sudden changes; the supply-demand equilibrium is also more stable.

(iii) Fragmented merchant markets. In this type of market, the product users are mostly smaller companies and more numerous, the market becomes more fragmented. Large intracompany transactions are rather exceptions, trades, brokers and distributors are involved Relation between manufacturers and users is less direct. Demand-supply equilibrium is more easily broken, prices are more subject to sudden changes.

(iv) Trading companies. During the late 1960s and early 1970s, a number of independent chemical trading companies took over a part of the marketing. However, despite all their efforts, the role of the traders has been diminishing in the last decade, as more and more chemical groups were setting their feet in the international market and establishing

sales offices abroad. There is in fact an in-built resistance towards middlemen by the large chemical companies who feel that using a trader reflects on their competence as marketers.

Among the product ranges under consideration, few products are the subject of trader attention.

(v) Distributors. Distributors are service-oriented companies who fulfill two main useful purposes:

(i) Selling and delivering the products of large chemical companies to small consumers,

(ii) Selling and delivering the products of companies who cannot afford the costs of their own sales force.

Most distributors own warehousing facilities and a fleet of delivery trucks, in addition to a sales force. Their lower overheads, flexibility and small size enable them to service a large number of small customers.

The distributor rarely, if ever, handles building block chemicals, but he is widely involved in markets such as phthalic anhydride and polymers such as HDPE, LDPE, PS, PVC or PP.

Table A.19 gives an overview of the different trading methods according to the petrochemical products.

The main principles involved in marketing may be summarized as follows:

- The further downstream (from ethylene), the more difficult and fragmented the markets become.
- The further upstream, the more stable the prices will be on the chemical markets, since most transactions are intra large companies.

Table A.19 Traded and non-traded products inbasic chemicals and intermediates

Non-traded company to company products	Moderate level of trader involvement	High level of trader involvement	Distributor involvement
Ethylene	Benzene	Styrene	Phtalic anhydride
Propylene	Paraxylene	Orthoxylene	HDPE
Butadiene	Ammonia	Phthalic Anhydride	LDPE
Ethylene dichloride	Ethylene Glycol	Methanol	PS
VCM			PVC
Acrylonitrile			PP
DMT/TPA			Solvents
Formaldehyde			Resins
			Fibres
			Specialities

Therefore, in attempting to enter markets in the industrialized areas, the developing countries' strategies must be product-based, in other words the type of product will determine the strategy used. For example, ethylene or VCM should be sold directly to end users by the supplier, whereas LDPE or styrene monomer may require quite a different approach.

It is not difficult to set up a marketing organization for basic chemicals because of the very restricted number of buyers. However, once a move downstream is contemplated, into products which are performance-oriented, such as plastics, the problems of marketing, technical support and distribution increase dramatically, so that a very careful analysis of the available options is needed.

2.3 Trade growth barriers

The penetration of developing countries into the market of the industrialized regions is encountering and will continue to encounter serious barriers, both visible and invisible, which can be summarized as follows:

(i) The developing countries have no serious presence, as yet, either with personnel or logistics facilities, in the developed nations. This lack of presence in itself is a serious obstacle.

(ii) The developing countries have very little direct experience in this business area. Whilst their undoubted knowledge of crude oil marketing will stand them in good stead for the sale of large bulk chemicals (such as methanol or ammonia), it will be of little value in tackling polymer markets. They have no experience in serious customer service and dealing with other specific marketing problems.

(iii) The industrialized areas are currently net exporters in akk field so there is no direct need for external supply of most products until after 1990.

(iv) In view of the low growth and high unemployment the industrialized areas are becoming much more protective towards their own domestic industries. This leads to more protective measures being adopted, through import quotas and tariff barriers that governments impose. The trade union pressure on industry/government to adopt such practices is also increasing. The difficulties encountered by Sabic to place the methanol from its new plant, in spite of the involvement of its multinational partner in the joint venture, are typical examples. The analysis of the Second World Wide Study[56/] has given a realistic forecast of the situation which has become reality: tariff barriers and import quotas as well as other restrictive measures are taken by many governments in order to protect their own industry. One study,[57/] using the UNCTAD Trade Policy Simulation Model estimated, that in 1980, the petrochemicals imports by the EEC, United States and Japan would have increased by 10.8 per cent from the developed countries and 8.1 per cent from the developing ones and create an additional trade of US$ 1.7 billion, if trade barriers would not have existed.

56/ Second World-wide Study on the Petrochemical Industry: Process of restructuring (ID/WG.336/3), pp. 184-191.

57/ Karen McCuster: Tariff and non-tariff measures in the world trade of petrochemicals.

(v) The GATT rules, although aiming at removing trade barriers and liberalizing all trade, may present obstacles sometimes in marketing in some developing countries. Regional co-operation agreements between several adjoining developing countries has brought this problem to daylight. If several countries co-operate together to implement a petrochemical plant in one of them and supply all the others with its products, until these also have similar plants, the tariff exemptions granted must be extended to all other imports too, opening the market to all. The young indigenous industry is not protected any more from the competition of the world market unless the tariffs are also applied on the product from the neighbor.

(vi) For the manufacturing of end products, DCs have to buy the necessary process licences when implementing a new plant. License owners are in most cases the big manufacturing companies having vested market interests.

To overcome these obstacles, developing countries have to adopt appropriate strategies and policies for successful marketing activity.

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